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PROCEDURES FOR EVALUATING PERFORMANCE OF WASTEWATER TREATMENT PLANTS, A MANUAL

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PROCEDURES FOR EVALUATING PERFORMANCE OF WASTEWATER TREATMENT PLANTS

A Manual

Prepared for

Environmental Protection Agency
Office of Water Programs
Washington, D.C.

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ABSTRACT

This manual establishes a procedure for the evaluation of the performance of wastewater treatment plants. It furnishes the information necessary to identify and classify various types of treatment plants. This manual details the processes commonly utilized in wastewater treatment. The common problems affecting plant operation are identified and described. The description first states the problem and then identifies the indicators of the problem, which are listed in order of their relative importance. The type of laboratory tests which should be performed are listed, along with other evaluation techniques. Finally, operational, maintenance, or other corrective measures are listed in order of their effectiveness.

References are given for an in depth review of unit and process operation and for additional information (where applicable). A glossary is also included.

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INTRODUCTION

The purpose of this manual is to provide technical guidance for persons conducting evaluations of wastewater treatment plants and serve as a model which can be used by state regulatory agencies.

It furnishes the information needed to facilitate identification and classification of various types of treatment plants. It also details the processes commonly utilized in wastewater treatment. The common problems affecting plant operation are identified and described. Several aspects of each problem are covered: exactly what is the problem; how it is detected, what are the possible causes, and what solutions are feasible.

It is assumed that the manual user has a general familiarity with both typical wastewater treatment plant design and operation, as well as a technical background in sanitary engineering. In addition, the user should complete a training program which includes the evaluation of a series of wastewater treatment plants using this manual and other evaluation methods.

As wastewater treatment technology is changing rapidly, this manual will be reviewed and updated routinely in order to maintain its effectiveness as a plant evaluation tool.

MANUAL FORMAT

In order for the manual to be an effective tool in the evaluation of wastewater treatment plants, familiarization with its structure as well as its advantages and limitations is necessary.

Like any other tool which is being used for a particular purpose, the manual can be utilized best by familiarization with:

- TABLE OF CONTENTS - so material can be quickly and easily located.
- GLOSSARY - to understand the manual terminology.
- PLANT OPERATIONAL DATA - to become familiar with operational parameters, loading rates, and support systems used with each unit operation.

- PLANT CLASSIFICATIONS - to give background information on the schemes, their processes, and their relation to a treatment system.

- PLANT EVALUATION PROCEDURES - to become familiar with the steps required in performing a plant evaluation.

- DATA FOR EVALUATION - an in-depth review of the data required in conducting a plant evaluation.

This manual contains four principal sections and several supplemental appendixes:

SECTION I	Procedures for Plant Evaluation. This section of the manual contains a step-by-step procedure for organizing information before the plant is visited and for performing the on-site evaluation.
SECTION II	Wastewater Treatment Systems Operational Data. This section of the manual contains data on the common operating parameters, loading rates, waste products accumulated from process operation, and the support systems which are used in the various unit operations and processes.
SECTION III	Sampling and Testing. This section of the manual contains information on the type of sampling to be done, location of sampling points, and analyses to be performed for the particular treatment system.
SECTION IV	Common Operating Problems and Suggested Solutions. This section of the manual is to properly identify problems which frequently occur in wastewater treatment plants and delineate which corrective measures should be implemented.
APPENDIX A through APPENDIX G	These appendixes supply the background information on the various treatment systems; how they are classified, personnel requirements, maintenance data programs, and information on the various unit operations.

Section I

PLANT EVALUATION PROCEDURES

The evaluation of a wastewater treatment plant consists of an in-depth analysis of the following basic elements:

- Plant performance
- Operational problems
- Operating personnel
- Sampling and testing program
- Laboratory facilities
- Maintenance data program.

Information and data for each element are gathered and analyzed in four interrelated phases, namely

1. Preparation for site visit
2. On-site inspection
3. Problem identification
4. Total plant evaluation.

The estimated evaluation time will depend on the size and complexity of the plant, the amount of preparation on the part of the investigator(s), and the willingness of the plant personnel to cooperate with the investigator(s).

For planning purposes the following table gives values which can be used for the initial evaluation. The estimate of the times required to perform a treatment plant evaluation will vary with the complexity of the treatment facility and other factors; this variation could be as great as 50 percent.

TREATMENT PLANT EVALUATION PERIOD

(days)

	Plant Size (MGD)		
	1	10	100
Preliminary Preparation	1/4	1	1½ to 2½
On-Site Investigation			
• Visual Inspection	1/4	1/2	1 to 1½
• Record Analysis	1	2½	2½ to 4
• Problem Evaluation and Solution	1	0 to 3	0 to 4
Written Report	1/2	1	1
Total Days (maximum)	3	8	13

PREPARATION FOR SITE VISIT

Preparation for the on-site inspection should include compilation and review of information which provides a description of the plant's physical setting, plant design details, plant operating personnel, and any available performance records, previous inspection reports, compliance orders, etc. Reference material relevant to the type of plant being evaluated should also be reviewed (see Section II and the Appendixes).

The following are specific steps suggested for use in preparation for the on-site visit:

1. Compile and Review Information on Plant's Physical Setting

Information describing the physical location of the plant will be required in the evaluation. The information should include the following:

(a) Classification of Treatment System

- Type of plant (see Appendix A)
- Contributory population (domestic, industrial, etc.)
- Wastewater system (sanitary, combined, etc.)
- Geographic-climatic effects (see Appendix A) to determine if extreme geographic-climatic areas could have an effect on plant performance. This should include both extremes of temperature and precipitation
- Determine, if possible, the characteristics of the plant's influent and effluent. This should include both values of the parameters measured by the plant (BOD_5, pH, COD, temperature, etc.), and flow quantity and variations with time.

(b) Identification of Discharge Requirements

For a particular plant location, this might consist of allowable COD, pH, BOD_5, etc., or any special controlling conditions such as a minimum DO and chlorine residuals. If the official data are not readily available from the plant, then try contacting local and/or state health departments and state, regional, and municipal pollutional control agencies. These agencies may be able to supply the needed information. These data should then be compared to the matrix, Table A-2 of Appendix A, which contains expected effluent quality criteria for various treatment systems.

2. Compile and Review Information Describing the Plant and Staff

This should be accomplished in advance of the plant visit, recognizing that most state agencies will have some sort of records and previous evaluations which can be used as a comparison between the past, existing, and optimum operation of the plant. The information required to make this comparison includes:

- Size of plant (design, average daily flows, peak flows)
- Type of unit operations
- Historical operating data
- Size of staff, their qualifications, and distributions of time spent between unit operations
- Review all relevant plant documents such as design drawings, operating manuals for various pieces of major equipment, and summary (or monthly) operating reports.

This information should be compared with sections of the manual or other sources which give information on the following:

- Wastewater treatment systems operational data (use design specifications, where available, or see Section II of this manual)
- Personnel requirements (see Appendix B)
- Classification of wastewater treatment plants (see Appendix A).

3. Prepare a Pre-Visit Evaluation Data Sheet

Data will be needed prior to the evaluation to insure adequate data-gathering at the time of the on-site visit. The pre-visit evaluation guide should include a summary of all background information.

ON-SITE INSPECTION[*]

The inspection of the plant should be accomplished in several phases with each phase being progressively more detailed. The visit(s) would typically consist of two phases:

Phase One--a general orientation and overview of the plant and its operation, including:

- Meet initially with plant engineer or chief operator. Have him describe the plant and its principal operating characteristics, on a schematic basis (this and the following steps are to help orient you to the plant, but also to give you an indication of how well the staff understands the system).
- Interview plant staff members, starting with plant superintendent and other supervisory personnel and working progressively through the appropriate operating personnel.
- Determine routine plant performance and compare this with design performance and norms section of the manual (see matrix, Table A-2, Appendix A).

Phase Two--problem identification with an evaluation as to effect on overall plant performance. This phase also includes the procedure for laboratory evaluation.

Problem identification begins with a tour of the facility. Have the plant engineer or operator give you a complete tour of the facilities. Watch for and inquire about:

- Excessive particles and/or floc flowing over overflow weirs
- Excessive grease and scum buildup
- Any unusual equipment such as special pumps, chemical feeders, temporary construction on structures or other jury-rigged systems which are being used to correct problems (or possibly causing them)
- Evidence of flow in by-pass channel to parallel units because problems have come up in normal operating units

---

[*] Always contact the plant manager in advance to set up an appointment; avoid ill-will from arriving unannounced.

- Excessive odors
- Abnormal color of wastewater in various process stages.

If any special plant modifications were made, determine:

- Purpose
- Physical makeup
- Effect on the other treatment processes by comparing old operational data with data after modification.

REVIEW RECORDS

In general, all records should be analyzed and compared with the information in the manual and/or other sources for consistency, method of calculation and to verify that recorded values are within the range recommended by this manual or other sources.

The following records should be reviewed:

FLOW. Hydraulic data are reviewed for:

- Consistency with the design flow and with present population served
- Over- and under-loading of the various treatment units.
- Meter calibration

UNIT OPERATIONAL DATA (BOD, COD, Suspended Solids, etc.) are reviewed for:

- Consistency with design specification and values indicated in the manual or other sources
- Extreme values for the daily flows.

POWER CONSUMPTION records should be reviewed for values above or below normal. These records would tend to indicate the following:

- Operating heads lower than the pump's rating
- Specific gravity or viscosity of liquids being pumped is too high.

POWER CONSUMPTION AND FLOW RECORDS. Analyses of the FLOW data in combination with POWER might indicate the following:

- Output of each pump separately and pumps collectively
- Unusual operating conditions which are in effect or have occurred
- Changes in efficiency of pumps by comparison of gallons pumped/kilowatt hour over an extended period of time.

MAINTENANCE DATA[*]. The maintenance program is usually a good indicator of operational quality; this can be indicated by checking:

- Manufacturer's maintenance schedule for components
- Type of routine being used for maintenance scheduling (as compared with Appendix H)
- Personnel qualifications for the type of maintenance work being performed.

PROCEDURES FOR PROBLEM EVALUATION

In general, the problems detailed in the manual are those most commonly encountered. However, these procedures can be used for any type of problem evaluation. The first step in problem evaluation is to determine if the plant is meeting design performance standards by comparing its effluent quality and overall removal efficiencies with those specified by the design (if design specifications are not available, compare the plant's performance against the guidelines given, see Appendix A). If the plant does not routinely meet performance specifications, it will be necessary to determine whether the deficiency is due to problems which fall into two categories:

PROBLEM DEFINED--If the treatment plant operator has defined the problem:

a. Verify general area of problems, such as related to process, maintenance or design, sampling, etc.
b. For common process problems, refer to that section of the manual dealing with the problem (see Section IV).
c. Develop sampling and testing program to provide additional data, if needed (see Section III).

PROBLEM UNSPECIFIED--If effluent discharge does not meet required standards and no definite problem area has been established:

a. Review flow and process records again in greater detail.
b. Recheck sampling and testing procedures required (see Section III).
c. Compare sampling and testing program against recommended programs in the manual.
d. Recommend a modified testing and sampling program to furnish additional data for evaluation (see Section III).

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[*] Refer to O & M manual requirements.

e. Compare the data with the problem indicators detailed in the manual (see Section IV) to see if there is a solution offered.

f. For those problems not specifically covered in the manual, and if the evaluator's experience does not suffice, should be recommended that a consultant be hired.

MAINTENANCE PROBLEM--Refer to sample maintenance program (see Appendix H) and compare with actual plant program; recommend new program where needed.

TOTAL PLANT EVALUATION

This should include the following:

1. TOTAL EVALUATION OF PLANT--utilizing the Evaluation Guide materials at the end of this section
    - (a) Modification of initial evaluation, if appropriate
    - (b) Differences in existing plant performance and operational data with design and/or manual operational or performance data
    - (c) Personnel needed for adequate operation*
    - (d) Type of sampling program required to give needed data
    - (e) Maintenance system needed
    - (f) Laboratory equipment needed
    - (g) Problems encountered
        - Those corrected by visit
        - Those that need outside help to correct
        - Proposed solutions.
2. FINAL REPORT--should contain the following elements:
    - (a) Summary of on-site visit
    - (b) A list of problems encountered
    - (c) Solutions recommended
    - (d) Proposed action.

---

* See EPA Staffing Guides.

Pre-Visit Evaluation Guide

Plant Identification (Name, Owner, etc.) ____________________
Plant Location ____________________
Operator in Charge ____________________
Date of Evaluation ____________________
Evaluation by ____________________
Date of Plant Construction ____________________
Name of Design Firm ____________________
Regulatory Agency of Concern ____________________
Stage Operating Permit? ____________________ Yes __ No __ Number ____

Background Information (obtain prior to visit whenever possible)

1. Type of Plant ____________________
2. Schematic of Flow Route to Units on Line
3. Contributory Population
    Domestic ____________
    Industrial (P.E.) ____________
    Other ____________
4. Type of Wastewater System
    Combined ____________
    Sanitary ____________
    Industrial ____________
5. Geographic/Climatic Effects
    Temperature Ranges (^{o}F) ______ to ______
    Rainfall Extremes (in.) ______ to ______

Sample

6. Plant Wastewater Characteristics

	Nitrogen (mg/ℓ)	Total Phosphorus (mg/ℓ)	BOD (mg/ℓ)	Suspended Solids (mg/ℓ)	COD (mg/ℓ)	Flow (MGD)	Dissolved Oxygen (mg/ℓ)
a. Plant influent							
b. Plant effluent							
c. Overall performance (%)							
d. Design and/or manual recommended performance values (%)							
e. Existing receiving water quality							
f. Required receiving water quality							

Sample

7. Possible Problems

a. Identified from operating reports

b. Identified from previous inspection reports

c. Complaints

On-Site Evaluation Guide

1. Flow

Design (actual)____

Daily Average____

Peak ____

Note any variation or erratic flow patterns.

2. Process Units Employed and All Pertinent Information

Unit Process	Operational Parameters		Loading Rates	
	Existing Plant Values	Design and/or Recommended Manual Values	Existing Plant Values	Design and/or Recommended Manual Values

Sample

3. Historical Operational Data

- Organize data to see if following occurred:

  Equipment failure - when, what type failure, how long out of service

  Extreme weather conditions

- Excessive loadings on plant:

  Flow -- when, how long, results of

  Organic - when, how long, results of

- Changes in process operation, such as:
  Increasing air flow to activated sludge units
  Decreases in detention times
  What caused changes? Are changes still in effect? Why?

4. Plant Personnel

Size of Staff for Daily Average Flow Handled		Qualifications		Types of Shifts (hours)	
Existing Plant	Recommended Manual and/or Other Sources	Existing Personnel	Recommended Manual and/or Other Sources	Existing	Recommended Manual

Sample

5. Laboratory Evaluation

Type of Tests Performed for Treatment System Evaluated			Testing Procedures and Equipment Used	Type of Tests Performed for Treatment System as per Manual
Type	Frequency	Location		

Guide for Overall Evaluation

	Yes	No
I. OPERATING PROBLEMS		
• Are there problems affecting the performance of this plant?		
• Can they be solved without major construction?		
• Are the skills to solve the problem available among the staff?		
• Was a solution suggested by the evaluator?		
• Is it a permanent solution?		
II. THE SAMPLING AND TESTING PROGRAM		
• Are the sampling locations suitable?		
• Are testing procedures "Standard methods?"		
• Is testing frequency adequate to maintain process control?		
III. LABORATORY FACILITIES		
• Is the laboratory well-organized and apparently functioning as intended?		
• Is there enough equipment to perform all the necessary tests?		
• Is the equipment being properly used?		
IV. PERSONNEL - Plant Operators (including lab personnel)		
• Is the staff adequate in size?		
• Are they qualified? State certified?		
• Is there an operator training program?		
• Are the shifts adequate and balanced?		

Sample

V. OVERALL PLANT PERFORMANCE	Yes	No
• Is it operating to its design specifications?		
• Is it meeting discharge requirements for its location?		
• Even if adequate, can plant performance be improved by simple and/or inexpensive changes?		
• ____________________		

Sample

Evaluator: If any of the answers are no, the following steps should be taken:

1. Submit a report which includes:
    - Summary of on-site visit
    - A list of problems encountered
    - Solutions recommended
    - Proposed action.
2. Discuss the recommendations with treatment plant staff.
3. In cooperation with the plant operator (and local officials, if necessary), decide on a course of action to solve the problem(s).
4. After a suitable period of time, revisit the plant to make a re-evaluation.

Section II

WASTEWATER TREATMENT SYSTEMS OPERATIONAL DATA

This section of the manual contains data on the common operating parameters, loading rates, waste products accumulated from process operation, and the support systems which are used in the various unit operations and processes.

Once the plant has been classified and the type of unit operations and processes have been determined, the information in this section will serve as a guide to evaluation of the overall plant operation. If operating and performance data are largely different, investigation of plant processes should be made to determine if the problem is with equipment or process failure. These should be noted, and if remedial solutions can be determined by use of this manual (Problem-Solution Section IV, this manual), they should be suggested to the plant operator. Where problems are beyond the scope of this manual, or experience of the evaluator, it should be suggested that the operator take the necessary steps to get proper outside help.

In the total evaluation of the plant, a list of problems encountered should be made and the steps that are being taken or were suggested to correct them. A return visit should be made after the operator has had sufficient time to correct the problems and a new evaluation made.

Table II-1

PRETREATMENT AND PRIMARY TREATMENT DATA *

Unit Operations or Process	Operational Parameters	Loading Rates				Accumulated Material (Sludges, etc.)	Support* Systems
Racks	Bar Spacing in Inches [2]					Cubic feet/MG [1]	Power for mechanically cleaned racks, conveyor belts, grinders
o coarse	1 - 2					3/4 - 3	
o medium	1/2 - 1					3 - 8	
o fine	1/32 - 1/4					5 - 30	
o mechanically cleaned	As small as 5/8 [3]						
Grit Chambers	Flow Velocity:	Mesh of Grit to Be Removed	Overflow Rate*** gal/sq ft/ day			Cubic feet/MG	Power for mechanical cleaning, cyclone operations, and for pumps to supply air. Conveyor system to remove grit.
o Air injected	0.75 to 1.0 ft/sec	35	73,000			2 - 8	
		48	51,000				
		65	38,000				
		100	25,000				
		Air Requirement: .025 to .05 cu ft/gal					
Cutters-Shredders (comminuters)	Capacities: 0.35 to 25 MGD [1] or 650-5,200 lb/hr						Power: 1/4 to 3.5 hp motor
Pre-Aeration	Detention Time: 15-45 min.	Air Requirement: [1] .005 to .2 cu.ft/gal or 25 - 40 psi Overflow Rates: [1] 2000-6000 gal/day/sq.ft				Volume of skimmings: 0.1 to 6 cu.ft/MG or 200 cu.ft/ 1000 person/yr	Cleaning units for diffusers, power supply for air supply.
Sedimentation	Detention Time [2] (hr)	Overflow Rates gal/day/sq ft					
Primary sedimentation before activated sludge	0.75 - 1.0	1,500 - 1,000				Sludge accumulation is approximately .038 cu ft/ capita or 3,500 gal/mg of flow	Cleaning mechanism for units without mechanical scrapers and skimmers. Sludge pumps and power supply for those with pumps and mechanical skimmers.
Inhoff tanks	2.5	600					
Primary sedimentation tanks before trickling filters	2.0 - 2.5	600 - 900					
Intermediate sedimentation between multistage trickling filters	2.0	1,000					
Final sedimentation after activated sludge	2.0	800					
Final sedimentation after standard trickling filters	2.0	800					
Final sedimentation after high-rate trickling filters	2.0	800					
		Weir loading rates: < 1 MGD; 10,000 gal/linear ft [4] > 1 MGD; 15,000 gal/linear ft					
Chemical Precipitation						Sludge contains chemical high water content and is twice the volume produced from plain sedimentation	Dosing, mixing, flocculation; and sedimentation units; where existing sedimentation units are not being used.
Chlorination [5]	Chlorine residual: 2 mg/l Contact time: 15 min	Probable Chlorine Requirements		Chlorinator [2] Capacities		Scum and grease accumulated in contact chamber.	Chlorinators, chlorine leak detection equipment, baffled contact tank unless adequate contact time is provided in a wastewater outfall or conduit. Safety equipment: Scott air packs, cylinder repair kits, ventilation system. Chlorine residual analyzer scales, evaporators, CPRV
Type of wastewater or effluent:		mg/l	lb/day per 1,000 persons*	mg/l	lb/1,000 persons*		
Raw wastewater, depending on strength and staleness		6-25	5-21	30	25		
Settled wastewater		5-20	4-17	25	20		
Chemically precipitated wastewater		3-20	3-17	25	20		
Trickling filter effluent		3-20	3-17	25	20		
Activated sludge plant effluent		2-20	2-17	25	20		
Intermittent sand filter effluent		1-10	1-3	15	12		

* For background information see Appendix C

** For wastewater flow of 100 gpcd

*** For approx. specific gravity of 2.31

NOTE:
1/ Steel
2/ Imhoff-Fair
3/ 10-State Standards, 1971 edition
4/ ASCE Std Manual
5/ Local requirements should prevail

Table II-2

SECONDARY TREATMENT DATA *

Unit Operations or Processes	Operational Parameters	Loading Rates	Support Systems
Trickling Filters	Recirculation Rate for Maximum BOD of Settled Wastewater BOD mg/l [1] Recirculation Ratio 130 1:1 170 2:1 220 3:1 260 4:1	Low Rate Filter High Rate Filter Hydraulic Loading gal/day/sq ft 25-100 200-1,000 million gal/acre/day 1.1-4.4 8.7-44 Organic Loading lb/1,000 cu ft/day 5-25 25-300 lb/acre ft/day 220-1,100 1,100-13,000	Dosaging tanks recycle pumps power supply
Intermittent Sand Filters	Depth of sand 3½-4 ft Head on filter, 5 ft	Loading 75,000-125,000 gal/acre/day Solids 2 lb/5 sq ft/day	Dosing siphon of flow distributor
Stabilization Pond or Lagoon[2]	Detention (days)** (months) Depth (ft) Algae Concentration (mg/l) [4]	lb/acre/day	
1. Large holding reservoir			
2. Stabilization pond			
(a) Facultative	7-30 2-5 10-50	20-50	
(b) High rate	2-6 ½-1 100	100-200	
3. Aerated lagoons	1 or 2 - 14 6-15		
4. Anaerobic	30-50 8-10	300-500	Aerators
Final clarification Following		Overflow Data gals/day/sq ft [3,5]	
Low-rate trickling filters		800-1,000	Sludge pumps, power supply for mechanical sweepers, pumps recirculation pump
High-rate trickling filters		800	
Activated sludge (over [illegible] mgd)		800-1,000	
Activated sludge (under [illegible] mgd)		800	
	Detention Time (hrs) for Overflow Rates & Depth of Tank[3] Overflow Rate gal/day/sq ft Depth 7 ft 8 ft 10 ft 600 2.1 2.4 3.0 800 1.6 1.8 2.25 1,000 1.25 1.4 1.75		
Package Aeration Plants	Flow Rate: 400 gpc/dwelling or 100 gpc/day Detention Time for: aeration tank 24 hrs clarifier 4 hrs Recirculation rate: 1:1	Organic load: 10-20 lb BODs/1,000 cu ft of areation tanks/day Air Supplied: 2,100 cuft/lb BOD/day	Power supply sludge pumps
Activated sludge System & ponds (see table)			

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* For background information see App. D.
** Unless otherwise noted

NOTE:
[1] Now parallel systems
[2] After 1960, Eckenfelder, O'Connor
[3] ASCE STD manual
[4] Algae concentration in suspension
[5] 10-State Standards 1971

Table II-3

SECONDARY TREATMENT DATA - ACTIVATED SLUDGE PROCESS

Unit Operations or Processes	Operational Parameters							Loading Rates		Support Systems
Types of Process	**Type of Mixing**		**Flow Scheme**			**Detention Time[2/] (hr)**	**Percentage Recycled Sludge**	**Loading[1/] lbs BODs/ lbs MLSS**	**Air Requirements[2/]**	
	Plug Flow	Complete Mixing	Aeration Only	Aeration & Sludge Return	Multi Stage Aeration & Sludge Return					
Modified Aeration (or high rate)	x			x		3 or less	10-50[3/]	1 or more	.41 ft^3/gal	
Conventional	x			x		1-6	15-75[5/]	0.2-0.5	.4-1.5 ft^3/gal or 700-1000 ft^3/lb BOD	
Contact Stabilization										Recycle pumps diffusers power supply sludge pumps air compressors air control system sludge aeration tanks
scheme 1	x				x	.5-1.0	50-150[5/]	0.15-0.2	750 ft^3/lb BOD removed	
scheme 2		x			x	Contact range 1-4 Stabilization tank		0.15-0.2		
Two Stage Aeration		x			x	Contact range 1.5-3.0 Stabilization tank 6-9		0.07-0.15		
Extended Aeration		x		x		24 hr	50-200[5/]	0.01-0.07		
Step Aeration						3-8	20-75[5/]	.2-0.5 of 50 lbs/1000ft^3 of tank	500-700 ft^3/lb BOD removed	
Completely mixed						3 or more	20-100[4/]	.3-.5	600 ft^3/lb BOD removed	
Oxidation Ditch (Passover Ditch)	Due to limited data at this time, no ranges for operational parameters or loading rates are possible.									

1/ lb of BOD lb mixed liquor suspended solids unless otherwise stated. American City, October 1971
2/ Steel, 1961. Manual for EPA "Up Grading Wastewater T.P."
3/ Minimum air requirement, according to 10-State Standards, is 1500 cu ft air/lb BODs except extended aeration which is 2000
4/ Steel
5/ 10-State Standards, 1971

Table II-4

ADVANCED WASTE TREATMENT DATA*

Unit Operations or Processes	Operational Parameters	Accumulated Material	Support Systems
Chemical/Physical Treatment	Capacities as for primary or secondary clarifiers	From 200 to 900 mg/l of additional sludge (for phosphorus removal)	Mixing basin for dispersion of added chemicals, pH measurement and control equipment
Carbon Absorption	Contact time: 15 to 45 minutes. Flow rates: 5 to 10 gpm/ft^2	From 50 to 120 mg/l of organic materials	Regeneration furnace Filtration equipment (where needed)
Ammonia Stripping	Air temperatures above 32°. pH between 10.8 and 11.5	Ammonia is carried off into atmosphere. Some carbonate scale and sludge buildup.	Power for forced draft. Coupling with phosphorus removal. Recarbonation equipment
Electrodialysis	Flow rate: up to 10 MGD. More efficient at higher temperatures	Brine stream 10-25% of feed stream	Electric power for stacks Brine disposal system
Reverse Osmosis	Flow rate: up to 50 MGD. More efficient at higher temperatures	Brine stream 10-25% of feed stream	Power for high pressure pumps (600 psi) Brine disposal system

*For background information, see Appendix E.

Table II-5

SOLIDS TREATMENT DATA*

Unit Operations or Processes	Operational Parameters		Loading Rates		Support Systems
Anaerobic Digestion	pH Temperature Detention Gas production	6.8-7.2 85-95°F 30 days 12 cu ft/lb volatile matter reduced	Loading of Heated Tanks,** lb volatile solids per cu ft per month[1]		Heat exchangers Circulation pumps o Gas o Sludge
Sludge produced for Anaerobic Digestion by:			Conventional operation	High-rate operation***	
Plain sedimentation			5.0	11	
Plain sedimentation and trickling filtration					
Low-rate operation			4.6	9	
High-rate operation			4.4	9	
Plain sedimentation and activated sludge					
High-rate operation			4.4	9	
Conventional operation			3.6	7	
Aerobic Digestion	Dissolved oxygen Detention times	1.0-1.5 mg/l 20-30 days			Supernatant Solids Removal Equipment
Sludge Thickening					
Gravity thickener			Overflow gal/sq ft/day	Loading lbs/sq ft/day	Sludge pumps Power supply
o Secondary sludge			400	8	Mechanical comb for water separation
o Activated sludge[3]			500	8	
Flotation					Diffusers Air supply Sludge pump
Sludge Drying Beds for:	Area in sq ft per capita: Open beds	Area in sq ft per capita: Covered beds			Sludge pumps
o Primary precipitation	1.00	0.75			
o Standard-rate filter[2]	1.25	1.00			
o High-rate filter [2]	1.50	1.25			
o Activated sludge[2]	1.75	1.35			
o Chemical precipitation	2.00	1.50			

* For background information see App. F.

** Tank at 90°F

*** Thickened to twice original solids content

NOTE:
[1] Table, Imhoff-Fair, Chapter 12
[2] These treatments include primary sedimentation
[3] Steel, p. 586

Note: Operational Parameters and Loading Rates information was not available for Sludge Thickening, Flotation, at time of publication.

Table II-6

COMMON SOLIDS TREATMENT DATA*

	Amounts of Chemicals Commonly Employed in Conditioning Unelutriated Sludge and Yields of Vacuum Sludge Filters									
	Conditioner, % of dry sludge solids							Conditioner, lb per 1,000 persons daily		
Type of Sludge	CaO	$FeCl_3$	Dry Solids lb per 1,000 persons daily	Filter Capacity lb per sq ft per hr, dry basis	Cake Solids %	Required Filter Area, sq ft per 1,000 persons daily	Sludge Cake, lb per 1,000 persons daily	CaO	$FeCl_3$	Support System
Plain sedimentation (primary)										Dosing equipment Power supply Sludge pumps Elutriation tanks Chemical storage
1. Fresh sludge	10	3	143	5	32	1.2	450	12	3.6	
2. Digested sludge	10	2	89	6	32	0.6	280	7.5	1.5	
	0	6	78	6	28	0.5	280	0	4.5	
Plain sedimentation and low-rate trickling filtration										
3. Fresh sludge mixture	12	3	183	4	28	1.9	650	18	4.4	
4. Digested mixed sludge	12	2	117	6	30	0.8	390	11	1.9	
	0	7	99	6	26	0.7	380	0	6.7	
Plain sedimentation and conventional activation										
5. Fresh activated sludge	0	6	71	2.5	20	1.2	350	0	4.1	
6. Fresh settled sludge mixture	0	6	195	4	22	2.1	880	0	11	
7. Digested mixed sludge	0	8	129	2.5	22	2.1	580	0	9.7	

*Adapted from Imhoff-Fair, 2nd edition. For background information, see Appendix F.

Section III

SAMPLING AND TESTING

INTRODUCTION

The sampling and testing program described in this section is designed to determine

- the type of sampling to be done
- the locations of sampling points
- the analyses to be performed for the particular treatment system.

In addition, recommended storage temperatures and durations are given, as well as a list of the laboratory equipment that will be needed to perform the various analyses. Sample forms are included which are intended as aids for the systematic recording of the results of the various analyses.

The information in this section can be used with the problem/solution section of this manual (Section IV) either to establish a sampling and testing program to solve a particular problem involving a particular process, or to institute an adequate sampling program at a plant lacking such a program.

A comparison of the type and frequency of tests needed to control the various processes with the sampling program actually being performed at the plant site can help evaluate the process control system of the plant. In the overall evaluation of the plant, this comparison would be used in ratings of the sampling and testing program, and the laboratory facility to perform necessary tests.

GENERAL

The characterization of waste, whether it be domestic or industrial in origin, begins with sampling. A wastewater treatment plant consists of various components which make up the treatment system. A program of sampling and testing which measures influent, effluent and individual process units on a scheduled basis not only means better plant performance but can also indicate problems quickly so that immediate corrective measures can be taken.

The extent of any testing program should depend on the size and type of treatment facility and the type and quality of receiving waters; however, it probably will depend on the time which can be made available for that purpose, together with the number of persons who staff the laboratory facilities. The treatment plant should be provided with adequate laboratory facilities for the performance of tests necessary for the proper operation of the plant.

Some more sophisticated treatment plants are provided with instrumentation which allows for constant monitoring of certain treatment processes and it is customary for this information to be telemetered and recorded at some convenient location within the plant control building. Telemetered information can include, but not be limited to, primary effluent pH, final effluent chlorine residual, aeration tank dissolved oxygen, and sludge density. Even though the instruments performing these monitoring functions can be highly reliable, it is recommended that their performance be checked periodically by analyzing concurrent and identical samples.

THE SAMPLING PROGRAM

A well-organized, effective sampling program must consider several factors:

- Type and scheduling of sampling needed for the specific analyses to be made
- Quantity of samples needed
- The most effective sampling locations
- Handling and storage procedures (between sampling point and testing site)
- Types of sample testing to be done.

Tables III-1 and III-2 indicate the common constituents which are analyzed from the flows of various treatment processes. The matrix (Table III-2) also indicates points in the treatment system where samples should be taken. The indicated sampling frequencies are minimum values and are dependent on or can vary with size of plant and staff, complexity of the system, the nature of the waste handled, and on the effluent requirements placed on the facility.

The test indicated should be performed as frequently as indicated in accordance with the prevailing requirements of the agency governing waste discharge within the area in which the plant is located. Every effort should be made to perform the tests in accordance with their scheduled frequency. A test with a "weekly" frequency should be run at a regular hour and day of the week.

Table III-1

PROCESS TESTING GUIDE*

PROCESS	TEST	FREQUENCY
	PRETREATMENT	
Grit Removal	Volatile Solids	Daily
	Total Solids	Daily
	Moisture Content	Daily
	PRIMARY TREATMENT	
Primary Sedimentation	Settleable Solids	Daily
	pH	Daily
	Total Sulfides	Daily
	Biochemical Oxygen Demand	Weekly
	Suspended Solids	Weekly
	Chemical Oxygen Demand	Weekly
	Dissolved Oxygen	Weekly
	Grease	Weekly
	SECONDARY TREATMENT	
Activated Sludge	Suspended Solids	Daily
	Dissolved Oxygen	Daily
	Volatile Suspended Solids	Weekly
	Turbidity	Daily
Trickling Filter	Suspended Solids	Daily
	Dissolved Oxygen	Daily
Oxidation Ponds	Dissolved Oxygen	Daily
	Total Sulfides	Daily
	Total Organic Carbon	Weekly
	Total Phosphorus	Weekly
	Settleable Solids	Daily
	pH	Daily
	Total Sulfides	Daily
Final Sedimentation	Biochemical Oxygen Demand	Weekly
	Suspended Solids	Weekly
	Chemical Oxygen Demand	Weekly
	Dissolved Oxygen	Weekly
	Turbidity	Daily
	MBAS	Weekly
	DISINFECTION	
Chlorination	Chlorine Residual	Daily
	MPN Coliform	Weekly
	SOLIDS HANDLING	
Thickening	Suspended Solids	Daily
	Volatile Solids	Daily
Digestion	Total Solids	Weekly
	Volatile Solids	Weekly
	pH	Daily
	Gas Analysis	Weekly
	Alkalinity	Weekly
	Volatile Acid	Weekly
Centrifuging	Suspended Solids	When in Operation
	Volatile Solids	When in Operation
Vacuum Filters	Sludge Filterability	When in Operation
	Suspended Solids	When in Operation
	Volatile Solids	When in Operation
Incineration	Ash Analysis	When in Operation
	ADVANCED TREATMENT	
Chemical Coagulation & Flocculation	Jar Test	Weekly
	Phosphorus Analysis	Weekly
Activated Carbon	Apparent Density	Weekly
	COD	Weekly
	TOC	Weekly
Recarbonation	pH	Weekly
Ammonia Stripping	Ammonia Nitrogen	Weekly
	pH	Weekly
Filters	Suspended Solids	Daily
	Turbidity	Daily
Microscreen	Suspended Solids	Daily
	Chemical Oxygen Demand	Weekly

*This is a minimum sampling guide, and is subject to change with plant site, complexity of operation, and problems encountered.

Table III-2

EQUIPMENT TESTING MATRIX*

EQUIPMENT NEEDED

CONSTITUENTS TO BE ANALYZED	Atomic Absorption	600° C Muffle Furnace	103° C Drying Oven	Analytical Balance	Imhoff Cone	pH Meter	Lamotte Kit	Biochemical Oxygen Demand Incubator	Vacuum Pump	Hot Plate	Kjedahl Unit	Condenser & Extraction Equipment	Dissolved Oxygen Meter & Probe	Autoclave	Amperometric Titrator	Sterilizing Oven	35° C Incubator	Gas Analyzer	Steam Bath	Magnetic Stirrer	Blender	Turbidity Meter	Carbon Adsorption Unit	Desiccator	Spectrophotometer	Stirring Equipment	Vibrating Shaker	Total Organic Carbon Analyzer	Purity Meter	Water Still
Volatile Solids		●	●	●																				●						
Total Solids			●	●																				●						
Settleable Solids					●																									
pH						●																								
Total Sulfides							●																							
Biochemical Oxygen Demand								●																					●	●
Chemical Oxygen Demand										●		●									●								●	●
Suspended Solids			●	●					●															●						
Dissolved Oxygen													●																	
Chlorine Residual															●															
MPN Coliform																														
Volatile Acids										●		●																	●	●
Alkalinity						●														●										
Gas Analysis																		●												
Grease			●	●					●	●		●							●											
Total Organic Carbon																												●		
Turbidity																						●								
Volatile Suspended Solids		●	●	●					●															●						
Total Phosphorous										●																				
MBAS																									●					
Sludge Filterability						●			●																					
Ash Analysis		●		●																										
Jar Test																										●				
Apparent Density				●																							●			
Iodine Number																														
Isotherms			●	●					●													●					●			
Calcium Content				●																				●						
Ammonia Nitrogen										●		●																		
Organic Nitrogen										●	●	●																		
Nitrate Nitrogen																									●					
Heavy Metals	●																													

*The equipment specified in this matrix is subject to plant size and complexity of processes and the degree of control required.

Types of Sampling

Sampling can be either of two types:

1. Grab. This type of sample is taken when wastewater does not flow continuously, when appearance of discharge changes rapidly, and when making sure that the composite sample isn't masking extreme conditions of the waste.

   It is also used when test samples cannot be mixed, such as when testing for residual chlorine, dissolved oxygen, or pH.

2. Composite. With the widely varying characteristics of waste, this type of sampling provides a representation of wastewater over a period of time and can be composited on the basis of proportional flow or the same amount being collected at every interval during the sampling period. Composites should be corrected as specified in Standard Methods.

Location of Sampling Points

Samples should be taken only where the wastewater is well mixed. If large particles are found in the sample, they should be broken up to make a more homogeneous sample. Deposits or growths of floating material which have formed at the sampling point should not be included in the sample.

Quantity of Sample

In order to determine the correct amount of sample to be collected, the past flow records of the plant should be analyzed to determine the daily average flow. The amount of the composite sample to be collected at a given period should be proportional to flow of wastewater at that time. Then determine the quantity of sample needed for analysis; 1 liter is usually sufficient; never try to work with less than about 200 ml.

Handling and Storage of Samples

Samples should be tested as soon as possible. If testing must be delayed, then adequate storage must be provided. Table III-3 recommends appropriate storage temperature and duration in terms of the test to be performed on the stored sample.

Table III-3

STORAGE TEMPERATURE AND TIME[1]

ANALYSIS	TEMPERATURE	TIME	TEMPERATURE	TIME
Total solids	4^oC			
Suspended solids	4 C	Up to several days	0^oC	No storage
Volatile suspended solids	4^oC	Up to several days	0^oC	No storage
COD	4^oC	Up to several days	0^oC	Unlimited
BOD		Up to one day in composite sampling systems		Lag develops, must use fresh sewage seed

Source: Agardy, F.J., and M.L. Kiado, Effects of Refrigerated Storage on the Characteristics of Waste, 21st Industrial Waste Conference, Purdue University, May 3-5, 1966.

[1] For more detailed preservation techniques, see Analytical Quality Control, EPA Chemical Methods, or Standard Methods.

Test Records

In order that the data developed through the plant sampling program can be properly utilized to gage plant performance, it is necessary that it be systematically recorded and filed for ready reference. The most practical means of satisfying this requirement is to prepare convenient forms on which these data can be recorded. These forms should be prepared to fit the particular operating conditions at each individual plant. The data should be recorded chronologically on these forms and should be organized so that each set of data can be utilized to evaluate a particular aspect of the treatment process. Proper recording of sampling data will allow for more efficient and expedient solution of operational problems. Several examples of operational forms are included at the end of this section which can be utilized for the recording of analytical data pertinent to the treatment process.

In addition to recording the data on forms, graphing of pertinent operating parameters may be appropriate and desirable for visual presentation.

For additional information on sampling and testing, see:

State of Washington Wastewater Plant Operator's Manual
Operation of Wastewater Treatment Plants: A Field Study Training Program, EPA
Effects of Refrigerated Storage on the Characteristics of Waste, 21st Industrial Waste Conference, Purdue University
Standard Methods, 13th Ed
Collection, Storage, Transportation and Pretreatment of Water and Wastewater Samples by Sanitation and Radiation Laboratory, California State Dept. of Public Health
MOP 11
MOP 18

SAMPLING PROGRAM FREQUENCY AND LOCATION

PARAMETERS TO SAMPLE

PROCESSES	GREASE	pH	FLOW	TEMPERATURE	TURBIDITY and/or CLARITY	SETTLEABLE SOLIDS	SUSPENDED SOLIDS	DISSOLVED SOLIDS	TOTAL SOLIDS	DISSOLVED OXYGEN	BOD	COD	VOLATILE ACIDS	ORGANISM COUNT and CLASSIFICATION	VOLATILE SOLIDS	VOLATILE SUSPENDED SOLIDS	GAS ANALYSIS	ALKALINITY	TOTAL SULFIDES	TOTAL ORGANIC CARBON	TOTAL PHOSPHORUS	SVI	MBAS	CHLORINE RESIDUAL
PRETREATMENT Grit Removal									③ d						③ solid									
PRIMARY TREATMENT	① ② w	① [illegible] w	[illegible] w	① d		① ② d	[illegible] w		[illegible]	① ② d	① ② w	① ② w	[illegible] w	[illegible] w	[illegible] w			[illegible] w	② d					② d
Sedimentation												③ w												
SECONDARY TREATMENT		① ② [illegible]	[illegible] d	① d		① ② w	① [illegible] w	① [illegible] d	[illegible] w	① ② d	① ② [illegible]	① ② [illegible]	[illegible]	[illegible] w	[illegible] w			[illegible] w						② d
Activated Sludge		㉑ d		㉑ d	③ d	① d	㉑ w	㉑ d		㉑ d				㉑ w		㉑ d						㉑ w		
Trickling Filter - Single Stage		⑦ d			② d	⑦ d	① ② [illegible]		⑫ ⑬ m	⑦ d					⑫ ⑬ m									
Trickling Filter - Two Stage		⑤ d				⑤ d	① ② [illegible]		⑫ ⑬ m	⑤ [illegible]	⑤ w	① ② [illegible]			⑫ ⑬ m									
Oxidation Ponds		① ② ㉒	⑨ d	① ㉒ d		① ② d	⑧ ② w			① ㉒ d	① w								㉒ d	㉒ w	㉒ w			② d
Final Sedimentation					③ d		③ w			③ w	③ w	③ w		⑯ w									③ w	
Package Aeration Plants		① ② d	⑨ d	㉑ d		① ② d				㉑ d														② d
Imhoff Tanks		① d ② ⑭ w	⑨ o			① ② d																		② d
DISINFECTION Chlorination														② w										② d
SOLIDS HANDLING Thickening									⑧ ③ d						⑧ ③ d									
Digestion		③ d		③ d					③ d				③ w		③ d		③ d	③ w						
Centrifuging									③ o						③ o									
Vacuum Filters									③ o						③ o									
Incineration	See Table III-1.																							
ADVANCED WASTE TREATMENT	See Table III-1.																							

FREQUENCY

daily	d
weekly	w
monthly	m
biweekly	b-w
bimonthly	b-m
when in operation	o

SAMPLING POINT

①	raw sewage
②	final effluent
③	process effluents
(3a)	primary effluent
④	secondary effluent
⑤	intermediate effluent
⑥	clarified effluent
⑦	filtered effluent
⑧	influent
⑨	influent or effluent
⑩	digester effluent
⑪	raw sludge
⑫	primary sludge
⑬	secondary sludge
⑭	above sludge blanket
⑮	digested sludge
⑯	receiving water
⑰	primary filter effluent
⑱	secondary filter effluent
⑲	primary supernatant
⑳	secondary supernatant
㉑	aeration tank
㉒	all of each lagoon or pond

NOTE: This is a minimum sampling program and is subject to changes with plant size and operational problems.

Figure 1. Sampling Program Frequency and Location

SAMPLE FORMS[*] TO BE USED WITH A SAMPLING AND TESTING PROGRAM ANALYSIS AND EVALUATION

---

[*] Forms to be developed and inserted by field inspectors.

COMMON OPERATING PROBLEMS
and
SUGGESTED SOLUTIONS

INTRODUCTION

There is a variety of common operating problems which may occur periodically and prevent the proper processing of wastes by a treatment plant.

The purpose of this section is to properly identify the problem by defining the indicators. Once the problem has been identified, certain monitoring, analyses and/or inspections must be performed prior to making a decision as to which corrective measures should be utilized. In some cases, the data-gathering process can be a simple visual observation and in other cases it can involve rather intricate sampling and laboratory procedures. The resulting information should then be systematically utilized to make a determination on which of the corrective measures should be implemented.

The problems discussed in this section are those which occur rather frequently in practice and the suggested solutions have been, for the most part, accepted procedure in the industry. There may be times when the suggested corrective measures do not correct the problem, or a problem may exist which does not fit into the common category. In a case such as this, it is prudent to seek expert advice on the subject prior to undertaking any course of action. The information utilized in development of the indicators and solutions reflect the present state-of-the-art; as information from new technical advances becomes available, this section will be updated.

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Problem

SURGING OF PLANT INFLUENT

Indicators

1. Intermittent flooding of weirs and structures.
2. Plant efficiency treating wastewater drops sharply for short period of time.
3. Flow meter records intermittent high and low peak flows.

Monitoring, Analysis and/or Inspection

1. If a main sewage lift station pumps effluent to plant, check for frequent starting and stopping of pumps or more than one pump operating at one time (out of phase) during a pumping cycle.
2. If influent flows to the plant by gravity through a main trunk, check depth of flow in connecting sewers if channel is uniform or monitor flow with a portable flow meter.
3. If surging occurs during rainfall, record relation of surging to duration of rainfall; and record or obtain rainfall intensity if possible.

Corrective Measures

2. Surging from gravity influent line indicates a major pump station discharge into a connecting sewer. Review water depth and/or portable flow meter data to determine source of flow.
1. Intermittent starting and stopping or recycling of main influent pump station or stations indicates improper wet well sensor adjustment or that the hydraulic capacity of the station has been exceeded. Adjust level sensors for a more desirable pumping cycle. If possible, install variable speed pumps units for uniform flow into treatment plant; or install surge tank.
3. Heavy surging or hydraulic loading of treatment plant treating waste from a separated system during periods of normal rainfall indicates illegal connections to system such as catch basins, yard drain, or roof downspouts. "Smoke bomb" sanitary sewer system to determine source of illegal connections.
4. Heavy surging or hydraulic loading of treatment plant during period of heavy rainfall is caused primarily by flooding of street areas and water entering the system through manholes, broken lines, etc. Seal all manhole covers in high risk flood areas and patch all cracks in manhole structures with an epoxy water resistant compound.

Problem

SURGING OF PLANT INFLUENT

Indicators

1. Intermittent flooding of weirs and structures.
2. Plant efficiency treating wastewater drops sharply for short period of time.
3. Flow meter records intermittent high and low peak flows.
4. Excessive suspended solids in overflows.

Monitoring, Analysis and/or Inspection

1. If a main sewage lift station pumps effluent to plant, check for frequent starting and stopping of pumps or more than one pump operating at one time (out of phase) during a pumping cycle.
2. If influent flows to the plant by gravity through a main trunk, check depth of flow in connecting sewers if channel is uniform or monitor flow with a portable flow meter.
3. If surging occurs during rainfall, record relation of surging to duration of rainfall; and record or obtain rainfall intensity if possible.

Corrective Measures

Surging from gravity influent line indicates a major pump station discharge into a connecting sewer. Review water depth and/or portable flow meter data to determine source of flow.

Intermittent starting and stopping or recycling of main influent pump station or stations indicates improper wet well sensor adjustment or that the hydraulic capacity of the station has been exceeded. Adjust level sensors for a more desirable pumping cycle. If possible, install variable speed pump units for uniform flow into treatment plant; or install surge tank.

3. Heavy surging or hydraulic loading of treatment plant treating waste from a separated system during periods of normal rainfall indicates illegal connections to system such as catch basins, yard drain, or roof downspouts. "Smoke bomb" sanitary sewer system to determine source of illegal connections.

4. Heavy surging or hydraulic loading of treatment plant during period of heavy rainfall is caused primarily by flooding of street areas and water entering the system through manholes, broken lines, etc. Seal all manhole covers in high risk flood areas and patch all cracks in manhole structures with an epoxy water resistant compound.

Problem ACCUMULATION OF SOLIDS OR SCUM IN WET WELL

Indicators

1. Scum blanket in wet well
2. Odors
3. Improper operation of level sensing equipment

Monitoring, Analysis and/or Inspection

1. Sound wet well with a pole to determine solids level.
2. Measure wet well draw down during pumping cycle.
3. Ascertain relation of pump suction piping to floor of wet well.
4. Determine elevation of inlet piping.
5. Look for dead spots in corners and structural cracks where sludge can accumulate.

Corrective Measures

1. Start pumps manually, being careful not to break suction, and pump wet well down to lowest possible elevation while breaking scum blanket with a high pressure water hose.
2. Check pumping level and determine if more of a drawdown can be allowed for in order to remove more of the floatable materials.
3. If one or more influent line come in at a higher elevation than the pump suction inlet, set level sensor so drawdown will allow for spillage of fresh wastewater onto the scum blanket. The resultant turbulence could assist in breaking the blanket.
4. If this is a persistent problem install air diffusers in wet well with compressors wired to operate in tandem with the pumps. Diffused air will assist in placing the solids in suspension and curtail the development of a scum blanket.

Problem ODOR SOURCE IN WET WELL

Indicators

1. Odors of hydrogen sulfide origin
2. Corrosion of iron work and concrete
3. Black color observed in liquid or solids

Monitoring, Analysis and/or Inspection

1. Hang hydrogen sulfide (lead acetate) indicator tiles in wet well.
2. Sample wastewater in wet well and analyze for total and dissolved sulfides.
3. Check for floating solids in wet well.
4. Run dye test on influent sewer or sewers to determine velocity of waste flow and travel time to wet well.
5. Check temperature of wastewater in wet well.
6. Check pump invert position and condition.
7. Check passage time in the interceptors at flow velocities.

Corrective Measures

1. Low velocities (less than 2 ft/sec) are an indication that solids are being deposited in influent sewer and sulfides are being formed and released in the wet well. Velocity must be increased in the sewer or influent must be continuously treated upstream with chlorine or copperous to prohibit the development of hydrogen sulfide gas.
2. If the source of hydrogen sulfide is in the wet well and not the influent sewer, increase pumping cycle for more frequent removal of solids.
3. Install air diffusers in wet well to keep wastewater fresh.
4. Install blower and gas scrubber for the oxidation of the gases and exhausting to the atmosphere.
5. Dose wet well with hyperchloride on a periodic basis to suppress the formation of hydrogen sulfide.

Problem

ACCUMULATION OF RAGS AND DEBRIS FOR DISPOSAL

Indicators

1. Large amount of rags and debris accumulated on plant site gives off obnoxious odors and attracts flies and other insects.

Monitoring, Analysis and/or Inspection

1. Estimate volume (cubic feet) of rags and debris removed each day in proportion to flow.
2. Determine time exposed material is allowed to accumulate.
3. Check disposal method used.

Corrective Measures

1. Arrange for local refuse or garbage company to pick up rags and debris on a daily basis and dispose of them in a sanitary fill.
2. Store rags and debris in closed containers whenever possible.
3. If incineration facilities are available on plant site or at some other convenient location, burn them. Care must be taken to see that the emission from the incinerator meets location air pollution control requirements.
4. Rags and debris can be disposed of on the plant site if sufficient land is available for a fill and cover operation.
5. If none of the above methods proves feasible, rags and debris can be ground up by installing the proper equipment and returned to the plant flow. This method should only be used as a last resort since ground or shredded screenings may cause problems in pumping equipment and in digesters.

I. PRETREATMENT - Screening and Shredding

Problem EXCESSIVE GRIT IN BAR SCREEN CHAMBERS

Indicators

1. Surging in chamber due to increase in water level.
2. Low removal of grit by degritting equipment.
3. Excessive dryout of grit with screening.

Monitoring, Analysis and/or Inspection

1. Sound chamber with flat board at end of pole to determine depth of grit.
2. Determine velocity in chamber by timing a dye release from one end of chamber to the other.
3. Check plans and probe bottom of chamber to determine whether there are any irregularities in chamber bottom slope.
4. Check channel when dewatering for regularly scheduled maintenance.

Corrective Measures

1. If velocity in chamber is less than 2 ft/sec. flush chamber regularly with high pressure water hose. If slide gates are available at inlet end of chamber, throttle gates to jet flow along chamber bottom.
2. Remove irregularities or reslope chamber bottom; if possible, to increase velocity.
3. Regulate velocity in grit chamber by utilizing different outlet weir shapes.

Problem	ODOR SOURCE IN GRIT CHAMBER
Indicators	1. Odors of hydrogen sulfide origin 2. Corrosion of metal work and concrete
Monitoring, Analysis and/or Inspection	1. Hang hydrogen sulfide (lead acetate) tiles in chamber. 2. Check velocities through grit chamber 3. Check volatile solids content of the grit. 4. Sample wastewater in chamber and analyze for total and dissolved sulfides. 5. Check for floating solids in chamber. 6. Measure depth of grit in chamber. 7. Check for submerged rags and debris on bar screen.
Corrective Measures	1. Clean bar screen thoroughly so as not to impede flow. 2. Increase velocity to 1 fps. 3. Wash grit chamber thoroughly daily with high pressure water hose to move sludge and floating solids through screens. 4. Dose chamber with hyperchloride on a periodic basis to suppress the formation of sulfide. Excessive doses of this chemical should be avoided as it can be toxic to biological treatment systems and anaerobic digestion systems. 5. Install blower and gas scrubber for the oxidation of gases and exhausting to the atmosphere.

Problem SHREDDED SCREENINGS, CLOGGING PUMPS

Indicators

1. Rope-like rags and debris wrapped around pump impellers.
2. Pump suction lines plugged with "bundles" of rags.
3. Excessive pump or drive beating and power requirements.
4. Appearance of chunks larger in size than usual in the shredder discharge.

Monitoring, Analysis and/or Inspection

1. Install pressure gages on discharge side of pump and check pressure daily.
2. If pump discharge line visible, check flow daily.
3. Check power input, bearing heat pressures on inlet and discharge sides.
4. Check driver speed and power train for power use and delivery to the shredder.

Corrective Measures

1. Do not shred screenings and return them to flow. Remove them either mechanically or manually and dispose of them by burial.
2. Check cutters periodically on all barminutors, comminutors, and other shredding equipment for sharpness.
3. Back flush pumps, periodically if possible.
4. If necessary, modify pump type, inlet protection or prior protective devices to avoid recurred plugging.
5. Upgrade screening and grit removal operation.

Problem GRIT REMOVED HAS HIGH ORGANIC CONTENT

Indicators

1. Grey color of grit
2. Odors from grit
3. Greasy feel with excessive components

Monitoring, Analysis and/or Inspection

1. Run volatile solids test on grit daily.
2. Check discharge pressure on cyclonic grit removal equipment.
3. Check velocities with dye releases in grit chambers.
4. If grit chamber is aerated, check air flow rate to chamber.
5. Visual examination of grit and identification of origin of grit materials.

Corrective Measures

1. Keep pressure on cyclonic grit removal equipment at an acceptable range (usually between 4 and 6 psi) by governing pump speeds.
2. Increase velocities in grit chambers by whatever means possible.
3. Adjust air accordingly.
4. Check inlet and outlet controls, baffles and mechanical equipment; adjust and repair and keep clean.

I. PRETREATMENT - General

Problem

INDUSTRIAL WASTE IS INADEQUATELY PRETREATED.

Indicators

1. Discoloration of influent
2. Sterilization of biological treatment processes
3. Digester upsets
4. Change in influent odor
5. Unusual amounts of solids in influent

Monitoring, Analysis and/or Inspection

1. Constantly monitor influent for pH above 8.0 or below 6.0.
2. Check pH of raw sludge.
3. Run heavy metal tests on influent.
4. Check influent temperature.
5. Run settleable solids test.
6. If toxic flow is constant, attempt to trace source upstream of treatment plant.
7. Run C.O.D. test on contaminated effluent and compare results with normal plant loading.

Corrective Measures

1. Bypass all biological treatment processes to parallel units as soon as contaminant has been detected.
2. Isolate and dispose of all contaminate sludges.
3. If digesters show increases in volatile acids because of contaminated sludges, see Section VII(b) for corrective measures.
4. If activated sludge process has become contaminated, dispose of floc and restart process.
5. Institute program of source control (industrial waste ordinances).

II. PRIMARY TREATMENT - Primary Sedimentation Tanks

Problem	FLOATING, GASEOUS, OR SEPTIC SLUDGE IN TANKS
Indicators	1. Floating material in tank deadspots or in scum troughs 2. Odors of hydrogen sulfide origin
Monitoring, Analysis and/or Inspection	1. Run total solids tests on raw sludge being pumped from primary sedimentation tanks with sample being taken at beginning and end of pumping cycle. 2. Dewater tanks and check sludge collector mechanism (flights, chains and scrappers) for wear and tear. 3. Observe conditions of tanks prior to chemical treatment of tank influent.
Corrective Measures	1. If total solids of raw sludge analyzed at end of pumping cycle is over 2%, increase duration of pumping cycle, preferably with a timer. 2. If sludge collector mechanism shows signs of wear during inspection, repair or replace. 3. Certain chemicals, such as alum, used in chemical treatment, cause floating sludge if this chemical is recirculated to the primary sedimentation tanks. Change operating procedures or chemicals used. 4. Long detention in sludge hoppers favors production of a sludge that readily slips.

II. PRIMARY TREATMENT - Primary Sedimentation Tanks

Problem LOW SETTLEABLE SOLIDS REMOVAL EFFICIENCY

Indicators

1. Floating and gaseous sludges in tanks
2. Percent settleable solids removal below 95%

Monitoring, Analysis and/or Inspection

1. Run settleable solids test (Imhoff Cone) during times of day where there are appreciable changes in plant flow.
2. Check raw sludge removal pumping cycles and duration of pumping period.
3. Run total solids test on raw sludge removed from tanks both at beginning and end of pumping cycle.
4. Dismantle and/or inspect raw sludge pumps and sludge collection mechanism for wear and tear.
5. Check tank inlets with relation to the tank outlets. If baffles have been installed on the inlets, dewater the tanks and check their condition.
6. Calculate theoretical detention time, weir overflow rates, and surface loading rates and compare all data with design criteria.
7. Try a dye test to estimate flow-through time. Check for density stratification due to significant temperature or density difference top to bottom.

Corrective Measures

1. If efficiency of removal drops during peak or increased plant flows, the hydraulic capacity of tanks has probably been exceeded. Refer problem to operating agency engineering staff.
2. Repair all worn raw sludge pumps, parts and sludge collector mechanism.
3. Damaged or missing inlet line baffles could cause tank short circuiting whereby increased velocities from one end of the tank to the outlet end cause settleable matter to remain in suspension. Replace or repair baffles.

Problem ERRATIC OPERATION OF SLUDGE COLLECTION MECHANISM

Indicators

1. Frequent replacement of broken sheer pins on chain driven collector mechanisms.
2. Frequent torque switch activated alarms on concentric driven clarifier equipment.
3. Visible slippage or "stuttering" of clarifier sludge collection mechanisms.

Monitoring, Analysis and/or Inspection

1. Check all drives for gear wear.
2. Dewater tank and check chains and sprockets for wear and see that chains have not come off sprockets.
3. Check to see that rags and debris have not entwined themselves around sludge collector mechanism.
4. Check dewatered tanks for excessive bottom deposits of sand, rocks and other inorganic material.
5. Sound bottom for excessive accumulation of sludge.

Corrective Measures

1. Repair all worn sludge collector equipment and drives.
2. If rags are a problem, make provisions for removal of all rags and debris as part of the pretreatment process.
3. If sand and rock deposits on the tank bottom are a problem, provide adequate screening and grit removal as a part of the pretreatment process.
4. If sludge accumulation is a problem, increase frequency of pumping raw sludge from tanks.

Problem

LOW SCUM (GREASE) REMOVAL

Indicators

1. Visible grease particles being discharges in plant effluent
2. Excessive water in scum pits

Monitoring, Analysis and/or Inspection

1. Run grease test (composite) on plant influent and effluent and calculate efficiency of grease removal equipment and compare with plant design criteria.
2. Observe if wooden flights making a return travel on tank surface carry grease particles adhered to them under scum troughs at the discharge end of the tanks.
3. Determine, with a pole, the depth of floating scum and water in scum pits.
4. Check capacity of scum pits.
5. Check for wear of scum pickup wiper blades.

Corrective Measures

1. If possible, lower return wooden flight to below water surface so grease particles do not adhere to them.
2. Install water sprays to direct grease particles on tank surface into scum troughs. Water spray should not break surface tension on water surface.
3. If scum removal is done manually and intermittently, continuous removal equipment should be installed.
4. Excessive water in scum pits should first be removed by pumping from bottom of pit to plant headworks and then the concentrated scum can be pumped to a digester or an incinerator.
5. Efficiency of scum removal in plants receiving a high grease loading can be increased by the addition of flotation or evacuator equipment.
6. Since grease particles normally in suspension tend to agglomerate into larger particles after being dosed with chlorine, chlorine contact tanks should be provided with grease removal equipment.
7. Pump scum pits down on a regular basis so as not to cause scum overflows back into the clarifier.
8. Clean and replace all worn wiper blades.

Problem TANK CONTENTS TURN SEPTIC

Indicators

1. Tank contents are a dark color
2. Hydrogen sulfide odors emitted from tanks

Monitoring, Analysis and/or Inspection

1. Run total and dissolved sulfide tests on both tank influent and contents.
2. Run DO test.
3. Check pH of tank influent.
4. Check quantity and total solids of all inflows into tank from other plant processes such as digesters supernatant, thickener overflows, centrifuge concentrates, etc.

Corrective Measures

1. If tank influent contains high dissolved and total sulfides, influent is septic. Prechlorinate influent or correct problem at source.
2. If tank influent pH is below 6 or above 8, toxic waste is being discharged into plant and must be corrected at the source.
3. If discharges from other plant processes contain excessive total solids and exceed 5% of the daily tank inflow, the sedimentation tank is being overloaded. If possible, reduce rate of process flows to sedimentation tanks or pretreat flows by aerating or chlorinating them. If possible divert or find other means of disposal for supernatant or centrates.

Problem SLUDGE BULKING

Indicators

1. Rising sludge in final clarifiers
2. Floating matter being discharged in final effluent
3. Filamentous growths in mixed liquor

Monitoring, Analysis and/or Inspection

1. Check mixed liquor for low pH and low dissolved oxygen.
2. Check sludge age, food/micro-organism ratio, or mean cell residence time.
3. Run settleability test and check for separation of floc in graduated cylinder or use Mallory Direct Reading Settleometer.
4. Check aeration period.
5. Check for NO_2 and NO_3.

Corrective Measures

1. If possible, reduce organic loads on aeration tanks affected.
2. Add digested sludge (that has been aerated for some time) to aeration tanks.
3. Dose the aeration tanks with alum or ferric chloride together with lime.
4. Controlled chlorination of return activated sludge.
5. Reduce sludge age and air rate to stop nitrification.
6. Increase sludge age by regulating waste sludge rate.
7. Increase or correct low dissolved oxygen or pH in aeration tank.
8. Increase aeration period by placing another aerator in operation if possible or reduce the return sludge rate by thickening the return sludge concentration by coagulation.
9. Control filamentous growth by increasing sludge age or supplementing nutrient deficiencies.
10. If nitrification is desired, maintain a minimum of 3 mg/l NO_3 and a maximum of 1 mg/l NO_2.

Problem

ERRATIC SLUDGE VOLUME INDEXES

Indicators

1. Pin floc visible in final clarifiers overflow
2. Poor settling characteristics of mixed liquor

Monitoring, Analysis and/or Inspection

1. Check mixed liquor suspended solids in each aeration tank.
2. Run 30 minutes settleability test in each aeration tank.
3. Determine whether the point floc is a recurrent situation or the result of toxicants.

Corrective Measures

1. Regulate wasting to decrease suspended solids in mixed liquor.
2. Chlorinate return activated sludge.
3. Decrease solids loading to aeration tanks.
4. Make appropriate adjustments to obtain a less oxidized sludge.

Problem

DIFFICULTY IN MAINTAINING BALANCED MIXED LIQUOR AND DISSOLVED OXYGEN IN AERATION TANK

Indicators

1. Intermittent sludge bulking
2. Loss of sludge blanket in secondary clarifier
3. Dark color in the aerator contents

Monitoring, Analysis and/or Inspection

1. Check D.O. concentration in different areas of aeration tanks during changes in daily flow.
2. Check suspended solids in mixed liquor at different periods during the day.
3. Run suspended solids test on aerator influent and mixed liquor to check sludge age.
4. Monitor rate of flow to aeration tanks.
5. Check daily flow variation in loading for excessive peak demand periods.

Corrective Measures

1. Lower D.O. concentrations occurring during changes in plant flow are an indication of excessive loading of aeration tanks. Increase air supply to tank if possible by placing another blower into service, etc.
2. Decrease loading to aeration tanks by placing more tanks into service if possible.
3. Provide controlled air supply to aeration tanks by interlocking blower speeds to tank D.O. monitoring equipment.
4. Increase inflow could hydraulically overload the secondary treatment system. If possible, bypass a portion of the flow from the primary sedimentation tank until the flow rate returns to normal.

Problem

EXCESSIVE FOAM IN AERATION TANKS

Indicators

1. Frothing in aeration tanks

Monitoring, Analysis and/or Inspection

1. Check influent for radical temperature changes.
2. Run M.B.A.S. test on influent.
3. Check suspended solids concentration in aeration tanks.
4. Check D.O. concentration in aeration tanks.

Corrective Measures

1. If practical, increase mixed liquor suspended solids by decreasing wasting rate.
2. Install or operate reclaimed water sprays in aeration tanks.
3. Utilize defoaming agent.
4. Lower air supply while being careful to maintain a safe dissolved oxygen concentration in aeration tanks.

Problem

DIGESTER SUPERNATANT AND/OR CENTRIFUGE CENTRATE UPSETTING ACTIVATED SLUDGE PROCESS

Indicators

1. Mixed liquor changes from a light to a dark brown color
2. Mixed liquor suspended solids decrease sharply during operation of centrifuge or when sludge is being pumped to digester
3. Final clarifier effluent increases in turbidity
4. Mixed liquid DO decreased.

Monitoring, Analysis and/or Inspection

1. Run total solids and pH tests on supernatant or centrate being returned to plant headworks.
2. Check mixed liquor suspended solids during discharge of centrate or supernatant.
3. Continuously check mixed liquor D.O.
4. Check volume of concentration of recycle flows relative to total plant flow.

Corrective Measures

1. Program discharges of supernatants or centrates so they do not coincide.
2. Pump centrates to digester whenever possible.
3. If centrates have high solids content, use flocculants in the operation of the centrifuge.
4. If supernatant have high solids content, experiment with supernatanting from a different level in the digester.
5. If possible, pre-aerate centrate and supernatants prior to discharging them to the activated sludge process.
6. Avoid discharging supernatants from septic digesters to activated sludge process.
7. If possible, release only small amounts of supernatant or centrate during periods of low inflow and increase return activated sludge rates if necessary.
8. Program recycles so that the return load does not exaggerate peak loading.

III. SECONDARY TREATMENT - Activated Sludge Process

Problem

UNABLE TO MAINTAIN BALANCED FOOD/MICRO ORGANISM RATIO IN AERATION UNIT

Indicators

1. Fluctuation in S.V.I.
2. Fluctuation in sludge age.

Monitoring, Analysis and/or Inspection

1. Check S.V.I. at least daily.
2. Check mixed liquor suspended solids at least daily.
3. Check suspended solids in influent and effluent at least daily.
4. Monitor plant flow, return activated sludge rate, and waste activated sludge rate.

Corrective Measures

1. Select and operate secondary treatment system by either Mean Cell Residence Time, Solids Retention Time, food/micro organism ratio, or sludge age.

Problem

FACILITIES INADEQUATE FOR DISPOSAL OF WASTE ACTIVATED SLUDGE (HIGH SUSPENDED SOLIDS IN THE CLARIFIER OVERFLOW)

Indicators

1. High suspended solids in mixed liquor
2. Increased turbidity in final clarifier effluent
3. High solids concentration in digester supernatants and sludge thickener effluents

Monitoring, Analysis and/or Inspection

1. Check S.V.I. at least daily.
2. Run C.O.D. and suspended solids of plant influent with and without supernatant and thickener return flows.
3. Check blanket depth level or high and low load periods.
4. Check inlet and outlet baffling for possibility of short circuiting.

Corrective Measures

1. If waste activated sludge is not settling in sludge thickener, increase flow of raw sludge to thickener or dose thickener inflow with coagulants.
2. Attempt to break "sludge cycle" by lowering wasting rate.
3. Re-aerate waste sludge prior to pumping to thickeners or discharging to primary clarifiers.
4. Change operation mode of aeration tanks to contact stabilization if possible.
5. If the sludge doesn't settle satisfactorily, coagulate with iron or aluminum, but adjust pH if necessary to keep aerator pH within 6.0-8.5.

Problem UNEVEN HYDRAULIC AND SOLIDS LOADING OF AERATION TANKS

Indicators

1. Mixed liquor suspended solids in each aeration tank varies considerably.
2. Dissolved oxygen in each tank varies considerably.

Monitoring, Analysis and/or Inspection

1. Run S.V.I. in each tank at least daily.
2. Run mixed liquor suspended solids in each tank at least daily.
3. Run dissolved oxygen in each tank at least daily.
4. Run suspended solids on influent and effluent.

Corrective Measures

1. Adjust valves and inlet gates to equalize flow to all tanks when operating under conventional mode.
2. Equalize air flow to all tanks by throttling valves on air discharge lines.

Problem ICE BUILDUP ON MEDIA

Indicators

1. Visible ice formation on filter media

Monitoring, Analysis and/or Inspection

1. Check air temperature.
2. Check recirculation rate to filter.
3. Check flow through filter orifices.
4. Check temperature of wastewater flow to filter.
5. Check filter surface for even distribution of flow.

Corrective Measures

1. By regulating amount of recirculation rate, adjust flow to filter to prohibit the formation of ice.
2. Adjust flows from orifices and splash plates to reduce spray effects.
3. Cover filter to reduce heat losses or install a windbreak to reduce chill factor.
4. Manually break up and remove major ice formations.
5. If possible, add hot water or steam to filter influent.

Problem	FILTER ODORS
Indicators	1. Odors of hydrogen sulfide origin present 2. Black slime visible on surface of filter media
Monitoring, Analysis and/or Inspection	1. Check dissolved and total sulfide of plant and filter influents. 2. Check filter drains for stoppages or growths. 3. Check rate of recirculation to filter. 4. Check for filter overflow or splashing.
Corrective Measures	1. If flow to filter is septic, correct in upstream system by aeration or controlled prechlorination. 2. Clear under drain system of all stoppages. 3. Force air into filter drain system to increase ventilation through filter media. 4. Increase recirculation rate to filter to increase D.O. and to slough off surface slime. 5. Keep areas around filters clean of slimes and growths. 6. Cover filter with inert material and exhaust air into an odor control/scrubber.

Problem	FLY NUISANCE IN VICINITY OF FILTER
Indicators	1. Tiny gnat sized flies becoming a nuisance in plant area and in neighboring area
Monitoring, Analysis and/or Inspection	1. Inspect grounds for tall grass, weeds and other sanctuaries for filter flies.
Corrective Measures	1. Increase rate of recirculation to filter to wash fly larvae out of filter. 2. If possible, flood filter for approximately 24 hrs. to prevent completion of life cycle of flies. 3. Apply a low dosage of chlorine being careful not to sterilize filter media. 4. Maintain grounds so as not to provide sanctuaries for flies.

Problem

CLOGGING AND PONDING OF FILTER MEDIA

Indicators

1. Ponding on filter surface
2. Intermittent flooding of filter

Monitoring, Analysis and/or Inspection

1. Check size of filter media for uniformity.
2. Check for cementing or breaking up of media.
3. Check for fibers, slime growths, trash, insect larvae, or snails in filter media voids.
4. Check organic loading on filter.
5. Check hydraulic load on filter.

Corrective Measures

1. If filter media is non-uniform and the smaller pieces fill the voids, replace the media.
2. Jet problem areas in filter media with a high pressure water spray from a stationary distributor.
3. Stir media manually to lessen or remove any accumulations.
4. Dose the filter media with chlorine at a rate of 5 mg/l for several hours a day during periods of low flow.
5. Flood filter media for approximately 24 hours to loosen surface accumulations.
6. Dry growth by drying filter for several hours, if possible.

Problem

CLOGGING OF DISTRIBUTOR NOZZLES CAUSES UNEVEN DISTRIBUTION OF FLOW ON THE FILTER SURFACE.

Indicators

1. Uneven sprays from distributor nozzles
2. Ponding on certain areas of the filter media with concurrent drying of other areas

Monitoring, Analysis and/or Inspection

1. Attempt to identify types or solids clogging nozzles.
2. Check for visible grease particles in waste being pumped to filter.
3. Run settleable solids test of waste being pumped to filter.

Corrective Measures

1. Remove and clean all nozzles and thoroughly flush distributor piping.
2. Improve primary clarifier skimming to prevent grease carryover to filter.
3. Increase detention time in primary tanks to prevent settleable and suspended solids carryover to filter.

III. SECONDARY TREATMENT - Oxidation Ponds

Problem	EXCESSIVE WEEDS AND TULES
Indicators	1. Excessive weed and tule growths 2. Mosquito problems in neighborhood of ponds 3. Poor pond circulation
Monitoring, Analysis and/or Inspection	1. Check water depths in selected areas of the pond.
Corrective Measures	1. Deepen all pond areas shallower than three feet. 2. Remove all weed and tule growths as soon as they are visible. 3. For mosquito control, vary liquid level in the pond every 10 days.

Problem POND ODORS

Indicators

1. Odors of hydrogen sulfide origin from pond
2. Other objectionable odors

Monitoring, Analysis and/or Inspection

1. Check for blue-green algae growths in pond.
2. Check for scum accumulation in pond.
3. Analyze for total and dissolved sulfides in pond and pond influent.
4. Check pond pH and pond influent pH.
5. Check DO content in pond at several locations.

Corrective Measures

1. If pond influent is septic, correct situation upstream by aeration or controlled prechlorination.
2. If possible, aerate pond with mechanical aerators.
3. Remove or break up all scum accumulations.
4. Prechlorinate pond influent.
5. If pond is septic, divert flow from aerobic pond to it or pump high D.O. make up water to it.
6. Add sodium nitrate to pond.
7. Provide odor masking agent if feasible.

Problem LOW POND DISSOLVED OXYGEN

Indicators

1. Low algae growth in pond
2. Trace hydrogen sulfide odors
3. Grey color of pond

Monitoring, Analysis and/or Inspection

1. Check all areas in pond for adequate D.O.
2. Monitor flow into pond and calculate average daily detention time in pond.
3. Check pH of pond influent and pond contents.
4. Run total and dissolved sulfides in pond influent.
5. Check pond loading rate (lb BOD/acre).
6. Check for floating aquatic weeds.

Corrective Measures

1. Increase detention time in ponds to at least five days by placing ponds in parallel.
2. In the absence of adequate D.O. in the pond, aerate pond contents or pond influent.
3. Chlorinate pond influent if sulfides are present.
4. Physically remove floating weeds to increase light penetration.

III. SECONDARY TREATMENT - Final Sedimentation

Problem

SLUDGE OR PIN FLOC FLOWING OVER WEIRS

Indicators

1. Particulate material rising to surface in clarifier
2. Effluent clarity poor

Monitoring, Analysis and/or Inspection

1. Check clarity of water in final clarifier with Secchi disc.
2. Measure turbidity of effluent discharged from clarifier with turbidimeter.
3. Attempt to determine height of sludge blanket in clarifier with depth sampler and/or a wooden pole.
4. Run suspended solids test on final clarifier effluent.
5. Check all sludge uptake piping to see that they are flowing freely and that 60% of the sludge removed is from inner 50% area of the clarifier.
6. Check pump rates and schedules of sludge withdrawal pumps.
7. Dewater clarifiers and check for damage on sludge scraper mechanism especially at the periphery of the tank.
8. Determine if the weir overflow rate is equal for the entire weir.

Corrective Measures

1. Increase pumping rate for greater removal of sludge from clarifier.
2. Wash down or clean all sludge uptake piping.
3. Repair or replace all damaged sludge scraper mechanism.
4. Level the weir.
5. If uneven weir overflow rate is caused from wind, install a windbreak.
6. Persistence of this problem would indicate a malfunction in the secondary treatment process.

III. SECONDARY TREATMENT - Final Sedimentation

Problem

ERRATIC OPERATION OF SCRAPER MECHANISM

Indicators

1. Frequent torque switch activated alarms on concentric driven clarifier equipment
2. Visible slippage or "stuttering" of clarifier sludge collection mechanisms

Monitoring, Analysis and/or Inspection

1. Check all drives for gear wear.
2. Dewater tanks and check for true travel of scrapper mechanism.

Corrective Measures

1. Repair all worn sludge collector equipment and drives.

Problem

CHEMICAL COAGULANTS UTILIZED FOR SETTLING OR DEWATERING SLUDGES THROUGH RECYCLING CAUSE FLOATING SLUDGES IN PRIMARY SEDIMENTATION TANKS.

Indicators

1. Floating and gaseous sludge floating in primary sedimentation tanks during periods of chemical treatment
2. Poor settling characteristics in the sludge
3. Poor sludge dewatering characteristics.

Monitoring, Analysis and/or Inspection

1. Determine types and amounts of chemicals used.
2. Conduct laboratory jar tests to determine effect of recycled chemicals on wastewater.
3. Check the dosing sequence, the rapid mix energy, and flocculation energy.

Corrective Measures

1. Correct the dosage of coagulants and alkalinity in line with process requirements on the basis of phosphorus content and a coagulant metal/phosphorus ratio of about 2/1. Institute a regular phosphorus determination and product turbidity control.
2. Correct coagulant concentrations and dose points to favor efficient chemical usage.
3. Make sure that sufficient rapid mix energy (800-1000 G) is applied for 1/2 to 2 minutes after dosage to mix substrate and coagulant. Follow with lower energy flocculation to agglomerate fines.
4. Adjust coagulant dosage in line with flow and concentration variations in the plant inflow. Monitor the treated overflow turbidity by the hour.

Problem	FREEZING IN AMMONIA STRIPPING TOWER
Indicators	1. Ice formation on outside face of tower 2. Drop in ammonia removal efficiency
Monitoring, Analysis and/or Inspection	1. Monitor ammonia removal 2. Check out water temperature for maximum and minimum values. 3. Check air circulation rate and distribution.
Corrective Measures	1. Use large flow distribution orifices at the outside face of the tower thus concentrating a curtain of warm water where the cold air first enters the tower. 2. Reverse draft fan to blow warm inside air outward to melt the ice. 3. If ammonia removal efficiency drops below 30%, take the tower out of operation.

Problem	FORMATION OF CALCIUM CARBONATE SCALE ON AMMONIA STRIPPING TOWER FILL AND STRUCTURAL MEMBERS
Indicators	1. Visible scale deposits in tower
Monitoring, Analysis and/or Inspection	1. Check pH of tower influent (ph has to be 10.5 or greater.
Corrective Measures	1. Hose off scale with water jet at periodic intervals. 2. Install water sprays in tower for jetting off scale at frequent intervals. 3. Clean tower with light solution of sulfuric acid.

Problem

FILTER BACKWASH WASH WATER HYDRAULICALLY OVERLOADS AND UPSETS CLARIFIERS

Indicators

1. Surging of clarifier during filter backwash operation
2. Higher turbidity in the treated flow

Monitoring, Analysis and/or Inspection

1. Determine amount and rate of filter backwash water being recycled to clarifiers.
2. Increase drum speed, backwash pressure or temperature, and backwash rate.

Corrective Measures

1. Collect backwash wastes in a storage tank and recycle at a controlled rate to clarifiers.

IV. ADVANCED TREATMENT - Microscreen

Problem	FOULING OF FABRIC WITH GREASE AND SOLIDS
Indicators	1. Loss of microscreen efficiency 2. Visible solids and grease on fabric
Monitoring, Analysis and/or Inspection	1. Run suspended solids test on influent to screen. 2. Check for upset in activated sludge process, if any.
Corrective Measures	1. Increase speed of drum. 2. Increase backwashing pressure. 3. Adjust backwashing cycles. 4. Backwash with hot water. 5. Backwash with an approved degreasing agent.

IV. ADVANCED TREATMENT - Microscreen

Problem	MICROSCREEN EFFLUENT EXHIBITS HIGHER SUSPENDED SOLIDS CONTENT THAN INFLUENT.
Indicators	1. Increased suspended solids and turbidity on discharge side of screens.
Monitoring, Analysis and/or Inspection	1. Determine colloidal solids in the influent to microscreens. 2. Determine total solids removal efficiency of microscreens. 3. Determine C.O.D. removal efficiency of microscreen.
Corrective Measures	1. Convert colloids in microscreen influent to suspended solids by adjusting the pH accordingly or by the addition of coagulants.

IV. ADVANCED TREATMENT - Activated Carbon

Problem MECHANICAL FOULING OF COLUMNS

Indicators

1. The flushing of accumulated solids from carbon columns is followed by an abrupt increase in the rate of absorption
2. Pressure rises in downflow columns
3. Decrease in flow rate.

Monitoring, Analysis and/or Inspection

1. Run suspended solids and total organic carbon of column influent and effluent.
2. Check for upset in secondary treatment process.
3. Check column operating routine and backwash records.

Corrective Measures

1. Bypass column influent with large amounts of suspended matter.
2. Flush columns frequently.
3. Consider upflow operation, filtration, or larger carbon grain size.

Problem

INSUFFICIENT CHLORINE GAS PRESSURE AT THE CHLORINATOR WITH ALL CYLINDERS CONNECTED TO GAS PHASE

Indicators

1. Chlorine pressure gage at chlorinator is reading too low.
2. Chlorine supply lines from cylinders are either very cold or are icing.
3. Chlorine cylinders or cylinder show a frost line.

Monitoring, Analysis and/or Inspection

1. Reduce feed rate on chlorinator to about one-tenth the rotameter capacity.
2. If after a short period the chlorine gas pressure rises appreciably it can be concluded that the rate of feed through the chlorinator is greater than the evaporation rate of the chlorine cylinders or cylinder at the prevailing ambient temperature.

Corrective Measures

1. Connect enough cylinders to the supply system so that the chlorine feed rate does not exceed the withdrawal rate of the cylinders. For 150 lb. cylinders the withdrawal rate at room temperature is 40 lbs. per day per cylinder; for ton containers it is 400 lbs. per day. At lower temperature it is less.
2. If insufficient cylinder capacity exists, do not try to apply heat directly to the cylinders, and do not heat the chlorine storage room with a space heater unless the control equipment (chlorinator) room can be brought to the same temperature.
3. The chlorine cylinder should always be kept cooler than the control equipment if possible; otherwise reliquefaction of chlorine may occur at the chlorinator.

Problem

INSUFFICIENT CHLORINE GAS PRESSURE AT THE CHLORINATOR

Indicators

1. Chlorine pressure gage at chlorinator is reading too low.
2. Chlorine supply lines from cylinders are either very cold or are icing.
3. There is icing or considerable cooling at one point in the chlorine header system between the cylinders and chlorinator.

Monitoring, Analysis and/or Inspection

1. Reduce feed rate on chlorinator to about one-tenth the rotameter capacity.
2. If icing condition or cooling effect does not disappear, mark the point where cooling begins and secure the chlorine supply system at the cylinders, but let the chlorinator continue to operate.

Corrective Measures

1. When chlorine gas pressure at chlorinator reaches zero and with chlorinator still operating, disconnect flexible connection to one chlorine cylinder. (This will allow chlorinator to evacuate residual chlorine in header system by replacing chlorine with air.)
2. Disassemble chlorine header system at point where cooling began. A stoppage or a flow restriction will be found at or near this point.
3. After the stoppage has been found it can be cleaned with a solvent such as tri-chlorethylene.
4. For massive build-up in black steel pipe header systems, the pickling process should be used. This consists of isolating the header system by disconnecting it from the cylinders at one end, the chlorinators at the other, and flushing with cold water until the water coming out is clear. The header then has to be dried with steam or hot air and final air drying to a dew point of -40°F.

Problem	THERE IS NO CHLORINE GAS PRESSURE AT THE CHLORINATOR, WHEN APPARENTLY FULL CHLORINE CYLINDERS ARE CONNECTED TO THE CHLORINE SUPPLY SYSTEM.
Indicators	1. Chlorinator gas pressure gage is at zero, inlet valve is open, all valves beginning with chlorine cylinder valve to the chlorinator are open.
Monitoring, Analysis and/or Inspection	1. Check the external chlorine pressure reducing valve installed just downstream of the chlorine cylinders.
Corrective Measures	1. If normal chlorine pressure appears at the chlorinator secure all the main chlorine cylinder valves, and start ventilating fans if available and arrange for maximum ventilation. 2. Put on a gas mask and gingerly break one flexible connection joint to release the gas in the header system. 3. Place a bottle of ammonia on the floor near the connection to be broken and when a white vapor appears leave the area as fast as possible and return only when the vapor disappears. 4. Repair the reducing valve which is probably plugged from the inherent impurities in chlorine gas. These units should be put on bi-annual overhaul. 5. Install a chlorine gas pressure gage upstream of the pressure reducing valve.

Problem

IMPOSSIBLE TO OPERATE CHLORINATOR BECAUSE ROTAMETER TUBE ICES OVER AND FEED RATE INDICATOR IS EXTREMELY ERRATIC. CHLORINE SUPPLY IS FROM TON CONTAINERS CONNECTED TO THE GAS PHASE.

Indicators

1. There is sufficient chlorine gas pressure and injector vacuum and the chlorine is at room temperature but the rotameter tube that indicates chlorine feed rate is nearly completely iced over.
2. The entire chlorine supply line back to the cylinder is also iced over, but cylinders are at about ambient temperature.

Monitoring, Analysis and/or Inspection

1. Inspect the chlorine cylinder area to see if they are connected properly. (This problem is specific to ton containers.)

Corrective Measures

1. Shut off main outlet valve on all cylinders and evacuate chlorine in header system until gage pressure at chlorinator reads zero.
2. Disconnect the cylinder that had icing on the flexible connection to the outlet valve and rotate it 180° and reconnect to top outlet valve and with other cylinders closed place this one in operation.
3. Tag cylinder so that packager can identify it as defective with possible broken dip tube but allow cylinder to remain in use until empty.

Problem

CHLORINATOR WILL NOT FEED ANY CHLORINE EVEN THOUGH ALL SYSTEMS APPEAR NORMAL.

Indicators

1. Chlorinator feed rate indicator shows little or no indication of chlorine flow when chlorine control valve is moved from closed to wide open position.
2. The chlorine pressure gage in the chlorinator is normal but the injector vacuum gage shows an abnormally high vacuum.

Monitoring, Analysis and/or Inspection

1. Check for an obstruction in the chlorine gas line near or at the inlet cartridge of the chlorine pressure reducing valve inside the chlorinator by shutting off chlorine supply system at chlorinator; chlorine pressure gage remains the same or moves downward in pressure at a very slow rate, i.e., one division per five minutes.

Corrective Measures

1. Shut off chlorine supply at the cylinders and try to let the chlorinator drain off all the chlorine gas pressure in the chlorine supply line.
2. If this cannot be done, turn on the ventilating equipment in the chlorine container space, if any, open all windows, don a gas mask and break a connection in the chlorine supply header but be absolutely sure that all chlorine cylinders have been secured.
3. When the gas has sufficiently cleared itself from the working area, disassemble the chlorinator chlorine pressure reducing valve to remove inlet cartridge and clean stem and seat with a soft cloth.
4. If this situation occurs regularly during hot weather, the source of the trouble usually is a result of the chlorine cylinders being hotter than the chlorine control apparatus.
5. Inspect cylinder area to see if anything can be done to make the area cooler.
6. Do not connect a new cylinder if it has been allowed to sit in the sun.
7. Install an external chlorine pressure reducing valve adjacent to the last chlorine cylinder connected to the supply system.
8. Precede the reducing valve by a combination chlorine filter and sediment trap.

Problem

CHLORINE GAS IS LEAKING FROM VENT LINE CONNECTED TO EXTERNAL CHLORINE PRESSURE REDUCING VALVE (CPRV).

Indicators

1. There is no visible indication of a malfunction.
2. Chlorine escaping from CPRV vent line.
3. Chlorine gas pressure, chlorine feed rate and injector vacuum are all normal.

Monitoring, Analysis and/or Inspection

1. Confirm leak by placing ammonia bottle near the termination of the CPRV vent line.

Corrective Measures

1. The symptom described indicates that the main diaphragm of the CPRV has been ruptured.
2. Remove the external CPRV after evacuating header system and replace with a jumper tube for temporary operation while valve is being repaired.
3. Disassemble valve and replace diaphragm.
4. Inspect the ruptured diaphragm to see if failure is from corrosion, improper assembly or just fatigue from length of service.
5. Consult manufacturer for expert opinion.
6. If failure is from corrosion the chlorine supply system should be inspected for moisture intrusion.

Problem

INABILITY TO MAINTAIN CHLORINE FEED RATE WITHOUT ICING OF CHLORINE SUPPLY SYSTEM BETWEEN EXTERNAL CHLORINE PRESSURE REDUCING VALVE AND CHLORINATOR. (EQUIPMENT CONSISTS OF EVAPORATOR, EXTERNAL CPRV AND THE CHLORINATOR.)

Indicators

1. Noticeable cooling of gas line to chlorinator beginning at outlet of external chlorine pressure reducing valve.
2. Evaporator water bath temperature is normal: 160 to 180°F.
3. Further cooling at point of pressure reduction in chlorine pressure reducing valve in chlorinator assembly.
4. Deposit of "gunk" on chlorinator feed rate indicator tube and what appears to be droplets of an amber color liquid.

Monitoring, Analysis and/or Inspection

1. Reduce feed rate on chlorinator to about 75 percent of evaporator capacity. If this or further reduction of feed rate eliminates the above symptoms, the difficulty is most likely to be insufficient evaporator capacity.
2. If chlorine gas temperature is available, calculate the superheat. If there is less than 5°F of superheat, there is very little reserve capacity in the evaporator. This is the result of an accumulation of sludge in the bottom of the liquid chlorine vessel of the evaporator.

Corrective Measures

1. Check for stoppage in the external CPRV cartridge if superheat cannot be measured.
2. Take the evaporator out of the system, flush and clean it with cold water and dry it in accordance with the manufacturer's instructions utilizing an "Evaporator Cleaning Kit." All evaporators should be routinely cleaned after passage of 250 tons of liquid chlorine.

Problem

CHLORINATION FACILITY CONSISTING OF EVAPORATOR-CHLORINATOR COMBINATION WITH EXTERNAL CHLORINE PRESSURE REDUCING AND SHUT-OFF VALVE IS UNABLE TO MAINTAIN WATER-BATH TEMPERATURE SUFFICIENT TO KEEP EXTERNAL CHLORINE PRESSURE REDUCING VALVE IN OPEN POSITION.

Indicators

1. External chlorine pressure reducing valve shuts off intermittently until water bath temperature is raised above 150°F.
2. Intermittent operation of chlorination equipment
3. Insufficient heat being supplied to evaporator water bath.

Monitoring, Analysis and/or Inspection

1. Check evaporator water bath temperature.

Corrective Measures

1. After evaporator has been in operation sufficiently long enough to bring heating elements to operating temperature, shut down power supply and remove and replace heating elements.

Problem

INABILITY TO OBTAIN MAXIMUM FEED RATE FROM CHLORINATOR OR CHLORINATORS WITH ADEQUATE CHLORINE GAS PRESSURE AT CHLORINATOR

Indicators

1. Chlorinator is placed into manual control and control valve is opened wide but chlorine feed rate will not go beyond 70 to 80 percent of maximum.
2. Check injector vacuum gage to see if reading is less than minimum recommended by manufacturer.
3. Check for injector vacuum reading below ten inches Hg.

Monitoring, Analysis and/or Inspection

1. Reduce feed rate on chlorinator.
2. If the injector vacuum reading increases then increase the injector water pressure.
3. Verify whether or not inlet water pressure to the injector is the same as when the installation was first installed.
4. Check injector water pump pressure against the manufacturer's operating data.

Corrective Measures

1. Disassemble injector and see that the throat and tailway are clear and without any abnormal deposition of iron or manganese, and clean the injector parts by soaking in nuriatic acid, rinse in fresh water and replace.

Problem	INABILITY TO MAINTAIN ADEQUATE CHLORINE FEED RATE
Indicators	1. Inspection of chlorinator reveals that chlorinator cannot feed as much as previously noted even though chlorine supply pressure is adequate.
Monitoring, Analysis and/or Inspection	1. If effluent is used check the injector operating water supply for deterioration in supply pump performance.
Corrective Measures	1. In the case of a centrifugal pump the only solution is a complete overhaul. 2. If a turbine pump, close down on the needle valve to maintain the proper discharge pressure. 3. If the turbine pump has worn sufficiently and it requires operation with the needle valve in the fully closed position, the pump should be thoroughly overhauled.

Problem

INABILITY TO OBTAIN MAXIMUM OR PROPER FEED RATE FROM CHLORINATOR WITH ADEQUATE GAS PRESSURE AT CHLORINATOR

Indicators

1. With chlorinator in manual control and chlorine control valve is manipulated to very the feed rate, the change of feed rate response seems sluggish and chlorinator will not achieve maximum feed rate.
2. The injector vacuum reading is borderline, and when feed rate is reduced the injector vacuum does not increase appreciably.

Monitoring, Analysis and/or Inspection

1. Check the chlorinator vent system for a small vacuum leak in the chlorine control apparatus by disconnecting the vent line at the chlorinator and while observing the chlorinator operation (feed rate and injector vacuum), place a hand over the vent connection to the vacuum relief device on the chlorinator. If this action produces more injector vacuum and more chlorine feed rate, it signifies that air is entering the chlorinator via this mechanism (vacuum relief device) because the springs have become weak due to normal metal fatigue.
2. Moisten all joints subject to a vacuum with ammonia solution or put paper impregnated with orthotolidine at each of these joints. With chlorinator operating at maximum feed rate, close the injector discharge line as rapidly as possible. If there is a vacuum leak in the chlorinator system it will be detected by either the ammonia or the paper.

Corrective Measures

1. If the vacuum leak is in the vacuum relief device, disassemble the mechanism and replace all the springs.
2. Repair all other vacuum leaks by tightening a joint, replacing gaskets, replace tubing and/or compression nuts.

Problem

EXCESSIVE CHLORINE ODOR AT POINT OF APPLICATION

Indicators

1. Air cover above area of chlorine diffuser reacts with ammonia solution to produce typical white wisps of "smoke" indicating escaping molecular chlorine.

Monitoring, Analysis and/or Inspection

1. Scattering ammonia indicator solution onto the wastewater stream over the area of the diffuser produces white fumes at the surface.
2. Check chlorine solution strength.

Corrective Measures

1. Add enough injector water to bring the chlorine solution strength down to 3500 ppm chlorine at maximum expected chlorine feed rate.
2. If the chlorine diffuser is situated below the injector which leads to a negative head in the solution line, install a special diaphragm protected chlorine solution pressure gage in the highest point of the chlorine solution discharge line and regulate the injector water flow so that there is a 2 to 3 psi positive pressure at this point.

Problem

CHLORINATOR WILL NOT FEED ENOUGH CHLORINE TO PRODUCE A PROPER CHLORINE RESIDUAL AT THE SAMPLING POINT.

Indicators

1. A routine spot check sampling shows that at some hours of the day there is an adequate residual but there are times during the day when there is no residual.
2. If there is a chlorine residual analyzer the chart will show periods during the day of insufficient chlorine residual.

Monitoring, Analysis and/or Inspection

1. Ascertain that if the chlorination equipment is being used for disinfection that it is equipped to proportion the chlorine feed rate in accordance with the flow of the wastewater.
2. If it is flow proportional, check to see if the meter capacity on the chlorinator matches the plant flow meter capacity.
3. Disconnect the flow proportional control and by manual control test the chlorinator to see if it will pull maximum feed rate.
4. Determine if solids have settled to the bottom of the contact chamber.

Corrective Measures

1. The automatic control features of the chlorinator should be repaired by the manufacturer's field service personnel who are equipped to simulate the various types of electric and pneumatic signals commonly used for chlorinator control.
2. If needed, clean the chlorine contact chamber.

Problem

WIDE VARIATION IN CHLORINE RESIDUAL IN EFFLUENT AS DETERMINED BY HOURLY CHLORINE RESIDUAL DETERMINATIONS

Indicators

1. Inability to adjust dosage so that there is reasonable agreement of chlorine residual throughout a 24-hour period as determined by occasional chlorine residual analysis at each shift.

Monitoring, Analysis and/or Inspection

1. While in flow proportional operation the feed rate of the chlorinator should be plotted on a piece of graph paper against the flow meter reading. The plots of wastewater flow versus chlorine feed rate should yield a straight line.

Corrective Measures

1. If the feed rate plots do not follow a reasonably straight line, it is well to recheck the zero and span of the flow proportional control device on the chlorinator. First make the zero check and then the span check in accordance with the manufacturer's instructions. If this does not correct the difficulty, it may be necessary to replace operating parts within the controller to achieve satisfaction.
2. If after the flow proportional control system on the chlorinator has been corrected the irregular chlorine residual reading continues, then it is recommended that a continuous chlorine residual analyzer be installed.

Problem

CHLORINE RESIDUAL ANALYZER RECORDER CONTROLLER DOES NOT APPEAR TO CONTROL THE CHLORINE RESIDUAL PROPERLY.

Indicators

1. Recorder draws a poor line on the chart that seems not to bear any relation to the "set point."

Monitoring, Analysis and/or Inspection

1. First check the loop-time in the system. This is best accomplished by turning off the gas supply to the chlorinator and determining the length of time required to show a sharp drop in the residual on the analyzer chart.
2. Disconnect the analyzer cell output leads from the cell and apply a simulated signal to the recorder mechanism from a manually controlled external signal generator. (Authorized chlorinator repair personnel carry such a device as part of their tool kits.)
3. Check buffer additive system to see if pH of sample going through the cell is maintained at 5 or less.
4. Check electrode bombardment system and see that electrodes are clean, particularly the noble metal electrode (Pt. or Au.). Do not disturb the copper electrode unless it is fouled with grease.
5. If residual analyzer is being used to measure total residual, check to see if sufficient potassium iodide is being added for the amount of residual being measured.
6. Reconnect cell output leads and make a zero, span and temperature check by following the manufacturer's procedure for a routine calibration.

Corrective Measures

1. If the loop time is found to be in excess of 5 minutes, satisfactory operation will not be achieved until the loop time is brought down to 5 minutes or less. This can be accomplished by moving the injector closer to the point of application, increasing the velocity in the sample line to the analyzer cell, by moving the cell closer to the sample point, or by moving the sample point closer to the point of application.
2. If the line on the chart indicates proper operation when subjected to a simulated signal, this signifies that the equipment between the cell and the readout of the pen is satisfactory. The erratic or poor line can either be caused by poor mixing of chlorine at the point of application or faulty operation of the cell. Poor mixing can be verified by setting the chlorine feed rate for a constant dosage (proportional to flow) and analyzing a great many grab samples over a ten minute period as quickly as possible. A poor mix will show rapid wide swings of the recorder pen. Consider mixing the point of application and/or install some type of mixing device to cause turbulence at the point of application.
3. If poor mixing is not the cause, and if the electrodes are clean, and if the pH and KI additive system is normal, then the difficulty must be in the cell and it should be replaced.
4. If when the simulated signal is applied to the recorder mechanism and the recording system does not respond properly, the difficulty lies in the electrical components of the recorder mechanism. Authorized service personnel should be summoned to correct the difficulty.

Problem

CHLORINATION SYSTEM CONSISTS OF EITHER COMPOUND-LOOP CONTROL OR DIRECT RESIDUAL CONTROL AND SYSTEM DOES NOT APPEAR TO BE CONTROLLING PROPERLY.

Indicators

1. Chlorine residual line on analyzer chart appears normal but does not track close enough to set point.

Monitoring, Analysis and/or Inspection

1. If the chlorine residual analyzer is operating properly, check the chlorinator system to see that it is functioning properly over its entire range of feed rate. Check to see if the chlorination system is feeding enough chlorine to satisfy the maximum demand; also check to see if the rotameter tube range is sized so that incremental corrections in feed rate by the residual controller are not too large. These two factors would cause wide swings in the chart line, or not allow the chlorine applied to ever actually "catch up" with the set point.

Corrective Measures

1. If the chlorination system will not feed enough chlorine, consult the corrective measures described previously under the problem of chlorination control equipment unable to feed enough chlorine.
2. If the chlorinator rotameter tube range gives too large or too small an incremental change, replace with a proper range of feed rate.

V. DISINFECTION - Chlorination

Problem

COLIFORM COUNT DOES NOT MEET THE REQUIRED DISINFECTION STANDARDS SET BY REGULATORY AGENCIES.

Indicators

1. Routine analysis of effluent or receiving waters shows MPN coliform organism to be in excess of that required by regulatory authorities.

Monitoring, Analysis and/or Inspection

1. Check capacity of chlorination equipment as follows: For primary effluent chlorinator capacity should be from 175 to 200 lb per MG. For secondary effluent 100 to 125 lb per MG and for tertiary effluent 75 to 100 lb per MG unless nitrogen removal is required. For the latter or for those plants requiring free residual chlorine, equipment capacity must be 10 mg/l of chlorine for each mg/l ammonia nitrogen in the effluent.
2. All chlorination equipment used for disinfection of wastewater effluent should have at the very least control proportional to the effluent flow. The capacity of the chlorinator should also be based on the maximum reading of the flow meter.
3. Continuously record the residual in the effluent with an amperometric type chlorine residual analyzer.
4. Check for short circuiting in contact chamber.

Corrective Measures

1. Chlorination equipment should be brought up to optimum capacity requirements. The necessary equipment should be installed to provide flow proportional control. In plants where only an influent meter exists, it may be required to install an effluent meter. After the proper primary meter is installed then the chlorinator can be modified by adding a chlorine orifice positioner to be operated either electrically or pneumatically from the primary meter.
2. A chlorine residual analyzer should be installed to properly monitor the chlorine control system. Using this apparatus to automatically control the chlorine dosage is optional; however, experience shows that the change in chlorine demand of most domestic wastewaters is significant enough to warrant the small added expense to accomplish automatic dosage control.
3. Install additional baffling in contact chamber.
4. If needed, install a mixing device in contact chamber.

V. DISINFECTION - Chlorination

Problem

COLIFORM COUNT DOES NOT MEET THE REQUIRED STANDARDS FOR DISINFECTION.

Indicators

1. Routine analysis of effluent or receiving waters shows MPN of coliform organisms to be in excess of the required standards.

Monitoring, Analysis and/or Inspection

1. Check to see if chlorine capacity is adequate, control system is functioning properly and effluent is being monitored with a continuous chlorine residual analyzer.
2. Check the chlorine contact time at low flow, average flow and maximum flow to determine the optimum residence time of the process. With this as a basis analyze five replicate samples for each hour around the clock on Monday, Wednesday, Friday and Sunday for coliform MPN after the following treatment: samples are to be taken from the effluent prior to point of application of chlorine and dosed in the laboratory with the same amount of chlorine as that applied by the chlorination equipment. The chlorine for this procedure should be taken from the plant chlorine solution line, standardized according to Standard Methods and added to one liter replicate sample of effluent. Upon addition the chlorine solution should be rapidly and thoroughly mixed, then allowed to stand for the amount of time determined previously at the optimum residence time. At the expiration of the residence time one portion of the samples should then be analyzed for chlorine residual using the iodometric back titration procedure while another portion should be dechlorinated and analyzed for coliform MPN in accordance with Standard Methods.
3. If the resulting coliform MPN from the above analysis is satisfactory, it is then reasonable to assume that the mixing at the point of application is at fault, because stirring chlorine in a batch process described above results in ideal chemical mixing.
4. Check for solids buildup in contact chamber.

Corrective Measures

1. If the difficulty is too low a residual raise feed rate and increase contact time if possible.
2. If poor mixing is the problem install a mixing device of high turbulence such as exists in an hydraulic jump or a combination of turbulent flow and mechanical mixer.
3. Clean contact chamber to reduce solids buildup.

V. DISINFECTION - Chlorination

Problem	PLANT EFFLUENT DOES NOT MEET TOXICITY REQUIREMENTS BECAUSE CHLORINE RESIDUAL TO ACHIEVE PROPER DISINFECTION IS AT TOO HIGH A LEVEL.
Indicators	1. Toxicity level is too high as determined by present bio-assay procedures.
Monitoring, Analysis and/or Inspection	1. Chlorine residual as determined by iodometric method using back titration method is deemed toxic to fish and other aquatic life in the receiving waters.
Corrective Measures	1. Install a dechlorination facility to operate in conjunction with the chlorination system.

VI. METERING

Problem

PLANT METER UNRELIABLE

Indicators

1. Drop or sharp increase in totalized dry weather flow
2. Overly uniform flow chart

Monitoring, Analysis and/or Inspection

1. If meter operates on a float, check float well for obstructions.
2. If meter operates on bubbler, check bubbler tube for damage. Also check air pressure gage to see that meter is getting proper air flow.
3. Bypass measuring weir or flume if possible and check to see if meter zeros.
4. Check height of flow over weir or in flume at different time intervals and, using the weir or flume characteristics formulas, calculate flow and compare with flow meter data.
5. Compare water surface elevation immediately behind weir or flume with elevation of water in float or bubbler well.
6. Ascertain the fact that none of the plant's process return flows (centrate, supernant, waste activated sludge, etc.) are discharged upstream from the meter.
7. Install a portable flow meter in the weir or flume and compare results with plant flow.
8. If metered flow discharges into a wet well or other chamber which has a known volume and outflow can be shut off, record time of measured rise in chamber and calculate inflow rate. Compare calculated data with meter data.

9. If wastewater treated at the plant is supplied by one or more utilities and the total amount of water used is metered, compare area water consumption with plant flow. During fall or early winter months, water consumed is approximately 10% more than wastewater discharged.

10. Check magnetic flow meter cores for grease build-up or restrictions.

Corrective Measures

1. Keep all floats and bubbler wells clean and free of grease by periodic maintenance.

2. Differences between inside and outside or bubbler well water surface elevations are due to extreme velocities in the immediate area of these wells. If possible, move wells to a more quiescent area behind the weir or flume.

3. Clean all foreign matter off weir plates.

4. If problem appears to be in the meter, recording or telemetering equipment, a qualified technician should be called in to repair and calibrate the metering equipment.

Problem	ODOR FROM THICKENER
Indicators	1. Odors of hydrogen sulfide origin 2. Floating or gaseous sludge in thickener 3. Corrosion of thickener concrete structure and metal work
Monitoring, Analysis and/or Inspection	1. Run total and dissolved sulfide test of thickener effluent. 2. Check pumping rate and frequency of pumping raw sludge from thickener. 3. Run total solids test on raw sludge pumped. 4. Dewater thickener and check operation of a scrapper and/or stirrer arms and sludge removal equipment. 5. Determine sludge blanket depth.
Corrective Measures	1. Adjust pumping rate to remove solids at a frequent rate and at not less than 3% total solids. 2. Repair or replace all damaged sludge collector mechanisms. 3. Cover thickener and exhaust gases to an odor control scrubber.

Problem

THICKENER CONTENTS DO NOT SETTLE

Indicators

1. Floating sludge on thickener surface
2. Floc in thickener effluent
3. Increased loadings on primary sedimentation tanks and secondary treatment process
4. Excessive sludge solids in the overflow
5. Poor concentration of underflow.

Monitoring, Analysis and/or Inspection

1. Run total solids on thickener effluent.
2. Run total solids in raw sludge withdrawn from thickener.
3. Run total solids of all thickener inflows and compare to thickener design capacity.
4. Run 30 minute settleability test of waste activated sludge inflow to thickener.

Corrective Measures

1. If thickener effluent contains high solids and the raw sludge withdrawn low solids, dose thickener with polymers or other coagulants.
2. If solids loading exceeds thickener design capacity, partially bypass thickener, if possible, by pumping raw sludge from the primary sedimentation tanks directly to the point of disposal, digester, or incinerator.
3. If waste activated sludge pumped to thickener does not readily settle, re-aerate or treat with coagulants.

VII. SOLIDS HANDLING - Sludge Thickeners

Problem SLUDGE PUMPED FROM THICKENER HAS LOW SOLIDS CONCENTRATION

Indicators

1. Thin or watery sludge discharged to point of disposal

Monitoring, Analysis and/or Inspection

1. Run total solids of raw sludge pumped from thickener.
2. Check pumping cycle and rate of pumping raw sludge from thickener.
3. Check rate of inflow to thickener.
4. Run total solids of thickener inflow.
5. Determine depth of the sludge blanket.

Corrective Measures

1. Adjust pumping rates and cycles, preferably with timers, and remove raw sludge from thickener at a density not less than 3% total solids.
2. Adjust thickener inflows to apply total solids to thickener of not less than 2%.
3. In gravity thickness adjust pumping cycles to maintain 3 to 4 ft sludge blanket.

VII. SOLIDS HANDLING - Sludge Digestion (Anaerobic)

Problem SCUM BLANKET IN TANK

Indicators

1. Decrease in digester gas production
2. Crust visible through sight glasses in digester roof
3. Unable to supernate from upper level of digester

Monitoring, Analysis and/or Inspection

1. Core blanket through digester thief holes to determine thickness.
2. Check digester temperature.
3. Check daily digester gas production.
4. Determine gallons of scum pumped to digester daily.

Corrective Measures

1. If possible, recirculate digested sludge from bottom of digester to top of scum blanket.
2. If digester has a gas mixing system, run system continuously while increasing digester temperature to not more than 105°F with the incremental increases not exceeding 1°F per day.
3. If digester has mechanical mixers with draft tubes, degassify digester, break up scum with a high pressure water jet and direct to draft tubes.
4. Clean digester and find alternate means of scum disposal.
5. If digester has gas mixer system, place temporary gas diffusers in thief holes and pipe compressed digester gas to them.

VII. SOLIDS HANDLING - Sludge Digestion (Anaerobic)

Problem NO DIGESTER GAS PRODUCTION

Indicators

1. Gas produced has septic odor
2. Gas produced does not ignite
3. Increase in digester volatile acids
4. Increase in volatile acid/alkalinity ratio

Monitoring, Analysis and/or Inspection

1. Determing digester volatile acid, alkalinity, and pH of digested sludge together with trend of volatile acid/alkalinity ratio.
2. Check gas meter and piping for restrictions.
3. Monitor volume of raw sludge pumped to digester daily.
4. Determine total solids, volatile solids, and pH of raw sludge pumped to digester.
5. Check digester temperature.
6. Sound digester to determine depth of scum blanket and grit residue on bottom.
7. Calculate volatile matter reduction in digester.
8. Check for toxic material in the digester.

Corrective Measures

1. If volatile acid to alkalinity ratio is greater than 0.2 and pH below 6.5 add lime to digester to decrease volatile acid/alkalinity ratio and increase pH.
2. Do not feed digester raw sludge in low pH ranges (less than 7.0).
3. If volatile reduction in digester is less than 50% decrease or discontinue feeding digester until pH rises.
4. Do not feed digester raw sludge with average volatile solids less than 75%.
5. If possible transfer digested sludge with a volatile acid/alkalinity ratio of 0.2 from another digester to affected digester.
6. If scum blanket and/or grit deposits comprise more than 50% of the effective volume of the digester, clean the tank.
7. Keep digester temperature at 98^{o}F.
8. Clean all restrictions in gas lines and/or meters.
9. If toxic material has killed digester, clean digester and determine source of toxicity to prevent recurrence.

Problem

INCREASE IN VOLATILE ACID/ALKALINITY RATIO IN DIGESTER

Indicators

1. Drop in digester gas production
2. Hydrogen sulfide odor from digester supernatant

Monitoring, Analysis and/or Inspection

1. Determine volatile acid, alkalinity and pH of digested sludge at least twice daily.
2. Check digester temperature.
3. Check pH of raw sludge pumped to digester.
4. Check mixing in digester.

Corrective Measures

1. If digester pH is below 6.5, add lime to digester.
2. If volatile acid/alkalinity ratio is greater than 0.4 decrease or discontinue feeding digester and add lime.
3. Do not feed digester raw sludges with pHs lower than 6.8.
4. Do not let digester temperatures drop below 90°F.
5. If possible, transfer sludge with low volatile acid/alkalinity ratio content from another digester to affected digester.
6. Keep contents of digester well mixed.
7. Decrease sludge withdrawal rates from digester.

Problem FOAM IN DIGESTER

Indicators

1. Foam discharged from upper level supernatant lines
2. Froth visible through sight glasses in digester roof

Monitoring, Analysis and/or Inspection

1. Determine total and volatile solids of sludge being pumped to digester and volume pumped.
2. Determine pH of digester contents.
3. Check digester temperature daily.
4. Monitor withdrawal rate of sludge from digester.
5. Ascertain depth and/or thicknesses of grit deposits and/or scum layers.
6. Check digester mixing program and effectiveness of mixing equipment.

Corrective Measures

1. Maintain digester pH between 6.8 and 7.2 and volatile acid/alkalinity ratio below 0.2 by adding lime.
2. Reduce or discontinue pumping raw sludge to digester.
3. Maintain digester temperature constant and at least at 95°F.
4. Attempt to thoroughly mix digester by recirculation or by available digester mixing equipment.
5. Break up scum layers or, if not possible, clean digester.
6. If possible, add digested sludge from a healthy digester.

VII. SOLIDS HANDLING - Sludge Digestion (Anaerobic)

Problem

LOW REDUCTION OF VOLATILE SOLIDS IN DIGESTER

Indicators

1. Volatile reduction calculates to less than 50%

Monitoring, Analysis and/or Inspection

1. Determine total solids of digested sludge and/or raw sludge being pumped to digester.
2. Monitor solids loading to digester daily.
3. Monitor solids withdrawal from digester.
4. Check total solids in digester supernatant.
5. Ascertain depths and/or thickness of grit deposits and/or scum layers.
6. Determine volatile acid/alkalinity ratio and pH of digested sludge.
7. Monitor digester gas production.

Corrective Measures

1. If total or volatile solids daily loading of digester exceeds design loading, reduce the amount of sludge pumped to the digester daily.
2. Keep digester temperature above 95°F.
3. Raw sludge pumped to digester should contain more than 50% volatile solids.
4. Recirculate and mix digester.
5. Prolong periods of withdrawing digested sludge until volatile reduction is above 50%.
6. Lower volatile acid/alkalinity ratio and raise pH above 6.5 by adding lime to digester.
7. If supernatant contains high solids content, let digester settle.

Problem HIGH PERCENT SOLIDS IN DIGESTER SUPERNATANT

Indicators

1. Supernatant very dark and thick
2. If supernatant is circulated to plant headworks, primary and/or secondary treatment processes efficiency drops severely.

Monitoring, Analysis and/or Inspection

1. Determine total solids of digester supernatant while supernating from different levels in the digester.
2. Determine total solids of digested sludge.
3. Monitor amount of raw sludge, activated sludge, and scum pumped to the digester daily.
4. Check pH of digester supernatant.
5. Determine length of time of digester mixing.

Corrective Measures

1. If supernatant contains more than 1% solids, do not mix digester and feed alternate digester if possible.
2. Supernate from digester level which gives the least solids in the supernatant.
3. Supernate from one digester into another if possible.

Problem LOW SOLIDS RECOVERING RATE

Indicators

1. Centrifuge efficiency falls below 60%
2. Solids in centrate exceed 3%.
3. Centrate very dark in color.
4. If centrate is recirculated to the plant headworks, the efficiency of primary and secondary treatment processes are directly affected.
5. Cake appears thick and quite wet.

Monitoring, Analysis and/or Inspection

1. Calculate centrifuge efficiency.
2. Monitor sludge feed rate to centrifuge and percent solids in sludge.
3. Monitor coagulant, if any, feed rate to centrifuge.
4. Check centrifuge for mechanical wear.
5. Check pool depth.

Corrective Measures

1. Decrease sludge feed rate to centrifuge.
2. Increase chemical coagulant dosage, if any.
3. Repair or replace all worn centrifuge parts.
4. Increase pool volume and bowl speed.
5. Reduce conveyor speed.

VII. SOLIDS HANDLING - Vacuum Filters

Problem: LOW SOLIDS RECOVERY

Indicator

1. High solids in filtrate
2. Poor clarity filtrate

Monitoring, Analysis and/or Inspection

1. Calculate filter efficiency.
2. Monitor coagulant, if any, feed.
3. Check filter mesh for blindings or coarseness.

Corrective Measures

1. Increase chemical coagulant feed rate.
2. Clean filter media.
3. Install fine mesh filter media.
4. Check sludge washing (elutriation) process.
5. Check filter drum speed and operation cycle.
6. Change types of coagulants being used.

Problem

ABNORMALLY HIGH TEMPERATURE IN FURNACE

Indicators

1. Temperature indicator exceeds limit of maximum operating temperature.
2. High temperature alarm activated.

Monitoring, Analysis and/or Inspection

1. Check rate of fuel consumption to determine if excessive.
2. Check to determine if fuel feed is off and temperature is still rising. Greasy solids may be present.
3. Check temperature indicator to see if it reads all the way up on the scale.

Corrective Measures

1. Decrease fuel feed rate, if excessive, in relation to sludge feed rate.
2. If temperature rises without supplementary fuel feed, greasy solids may be present in sludge. (This occurs infrequently when 100% primary sludge is incinerated.) To lower temperature, raise air feed rate while holding sludge feed rate constant. If air feed rate is at maximum, reduce sludge feed rate slightly.
3. If temperature indicator is all the way up the scale, this is an indication that the termocouple well is burned out. Replace thermocouple with spare unit, repair or replace thermowell with spare.

Problem	ABNORMALLY LOW TEMPERATURE IN FURNACE
Indicators	1. Temperature indicator shows low on scale.
Monitoring, Analysis and/or Inspection	1. Check calorific value of sludge to determine if it is decreasing. 2. Check moisture content of sludge to determine if it is increasing. 3. Determine level of excess oxygen in stack.
Corrective Measures	1. If calorific value of sludge is low, or if sludge moisture content is high, increase the supplementary fuel feed rate. 2. If excess oxygen is abnormally high in stack exhaust, reduce the air feed rate slightly or increase sludge feed rate.

Problem

HIGH OXYGEN LEVEL IN FURNACE STACK EXHAUST

Indicators

1. Oxygen analyzer (recorder chart) indicates excessive oxygen in stack exhaust

Monitoring, Analysis and/or Inspection

1. Determine total and volatile solids of sludge fed to furnace.
2. Check to determine if sludge is being fed to incinerator.

Corrective Measures

1. If sludge being fed to furnace is low in solids, increase the speed of sludge pump which feeds centrifuge. If the air feed rate is low and the sludge rate at a maximum and the exhaust oxygen is still high, shut down. The sludge supply to the furnace is inadequate.
2. If sludge is not being fed to incinerator, check for blockage of sludge in feed chute and check sludge feed pump stator. Unplug chute or repair stator if not in good condition.

Problem	LOW OXYGEN LEVEL IN FURNACE STACK EXHAUST
Indicators	1. Oxygen analyzer (recorder chart) indicates low oxygen in stack exhaust.
Monitoring, Analysis and/or Inspection	1. Check volatile content of sludge fed to furnace to determine if increasing. 2. Check sludge for grease content to determine if increasing. 3. Check to determine if air flow to furnace is restricted.
Corrective Measures	1. If the volatile content of the sludge is increasing or if the grease content of the sludge is increasing, increase the air feed rate. If the air feed rate is at maximum decrease sludge feed rate. 2. Remove any restrictions or blockages in air conduits.

VII. SOLIDS HANDLING - Sludge Lagooning

Problem

EXCESSIVE SOLIDS CARRIED OVER FROM LAGOON SUPERNATANT TO PLANT INFLUENT

Indicators

1. Dark supernatant discharged from sludge lagoons
2. Solids removal efficiency of plant treatment processes is lowered.

Monitoring, Analysis and/or Inspection

1. Determine total and suspended solids of lagoon supernatant.
2. Measure depth of sludge in lagoons.
3. Check for broken dikes between lagoons.
4. Check rate and volume of application of digested sludge to lagoons.
5. Determine total solids of sludge being applied to lagoons.

Corrective Measures

1. Reduce volume of sludge applied to lagoons thereby reducing depth of sludge in lagoon.
2. Repair all broken dikes between lagoons.
3. Delay release from lagoons of supernatant with heavy solids content until sludge is allowed to settle.

Problem	ODORS FROM SLUDGE LAGOONS
Indicators	1. Obnoxious odors from sludge lagoons.
Monitoring, Analysis and/or Inspection	1. Determine volatile acid/alkalinity ratio and pH of digested sludge being applied to lagoons. 2. Determine total and dissolved sulfide of lagoon supernatant.
Corrective Measures	1. If volatile acid/alkalinity and pH tests indicate a sour digester, attempt to correct problem at source. 2. Apply lime to surface of lagoon. 3. Install peripheral odor control system. 4. Flood lagoon with heavy chlorinated water.

Appendix A

CLASSIFICATION OF WASTEWATER TREATMENT PLANTS

This section of the manual contains information for the classification and identification of wastewater treatment plants by various designations. These include:

- Definitions of the classes of plants by function
- Operator classification
- Geographic location and climatic conditions
- Common processes and operational units

Also included is a matrix by which treatment systems are classified by their unit operations, removal efficiencies and expected effluent quality.

This section is used by:

- Isolating treatment system (by various classification)
- Determining the units which fall into that general system
- Learning the performance capabilities of the system.

This information, along with operational data for the particular system from Section II of this manual, is compared to the performance and operational data of the plant being evaluated and is to be considered in the overall evaluation of the plant.

CLASSIFICATION BY FUNCTION

Following are generalized definitions of classes of treatment plants according to their functions:

1. Primary treatment - Those wastewater treatment plants that employ methods which remove or reduce a high percentage of the suspended and floating solids but little or no colloidal and dissolved matter.
2. Secondary treatment- Those methods which remove or reduce fine suspended colloidal, dissolved solids, and cause the reduction of organic material by biological oxidation.
3. Advanced waste treatment - Those methods which remove or reduce nutrients, residual organics, residual solids and pathogens by, but not limited to, sand filtration, chemical treatment, carbon absorption, ammonia stripping, electrodialysis or reverse osmosis.

OPERATOR CLASSIFICATION

The classification system used in the area of the plant being evaluated should be reviewed to see if the proper personnel are being utilized for the existing treatment system.

Table A-1 shows the diversification of wastewater treatment plant classifications as denoted by their type, design flow and population served, contrasted with the class of operator which should be capable of operating them. These classifications have been established by the California Water Pollution Control Association and the California State Water Resources Board. Evaluators should be aware that most states will have their own classification system.

Table A-1

OPERATOR AND TREATMENT PLANT CLASSIFICATION

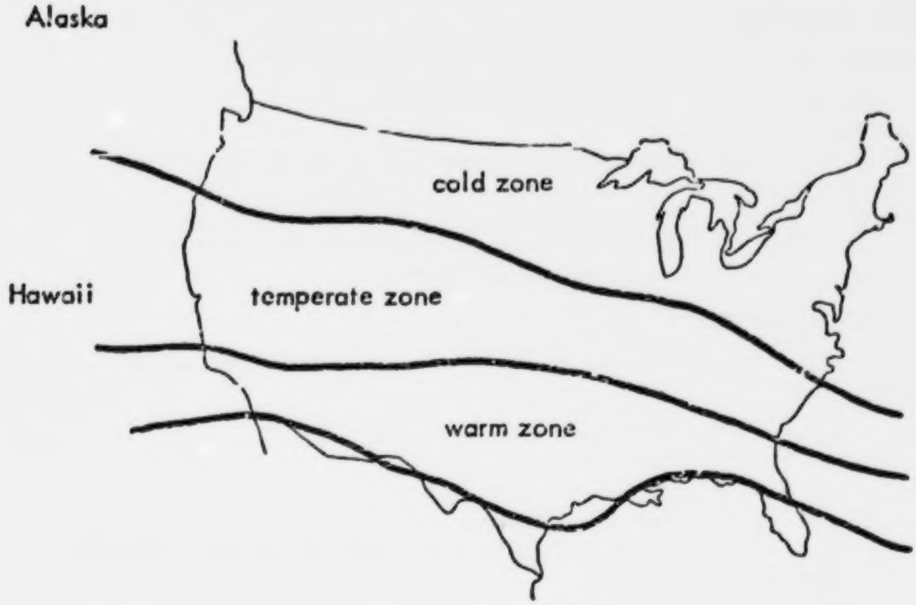
California Water Pollution Control Association	California* Operator Classifications	Treatment Process	Design Flow (MGD)	Population Served
IV	I	Stabilization Pond	All	2000
		Primary	1 or less	
III	II	Primary	1-5	2000 to 10,000
		Biofiltration	1 or less	
II	III	Primary	5-20	10,000 to 40,000
		Biofiltration	1-10	
		Activated Sludge	5 or less	
		Tertiary	1 or less	
I	IV	Primary	20 & over	40,000
		Biofiltration	10-30	
		Activated Sludge	5-20	
		Tertiary	1-10	
Ia	V	Biofiltration	30 & over	
		Activated Sludge	20 & over	
		Tertiary	10 & over	

*Classification adopted by the State Water Resources Control Board

Temperature zones and their approximate sphere of influence, along with probable effects on operating efficiencies, are defined below.

1. Cold Zone - average January air temperature of 30 F or less will cause a decrease from 4 to 5 percent in operating efficiency
2. Temperate Zone - average January air temperature of 35 to 45 F will cause a decrease of 4 to 5 percent at the 35 F range but normal operation at the higher temperature
3. Warm Zone - average January air temperature of 50 to 70 F allows normal operation at the low temperature and a possible 4 to 5 percent increase in efficiency at the higher range.

The following sketch delineates the approximate climate zones in the United States.



LOCATION OF TEMPERATURE ZONES
IN THE UNITED STATES

COMMON PROCESSES AND OPERATIONAL UNITS

The purpose of this subsection will be to identify all of the operational units and processes common to wastewater treatment plants operating in the primary, secondary and advanced waste treatment mode.

While every treatment plant can be considered unique, it is obvious that most treatment plants will have many operations and processes in common. Below is a list of the most common units used in various treatment modes.

Pretreatment

To remove or reduce floating solids and coarse suspended solids, use:

Racks
Medium screens
Grit chambers
Skimming tanks

Primary Treatment

To remove or reduce fine suspended solids, use:

Fine screens
Sedimentation
a. Plain sedimentation tanks, with or without mechanical sludge-removal devices
b. Septic tanks (biological action also takes place)
c. Imhoff tanks (biological action also takes place)
d. Chemical precipitation tanks

Secondary Treatment

To remove or reduce suspended colloidal and dissolved solids, oxidize with

Filters - intermittent sand filters
          contact filters
          trickling filters
Aeration - activated sludge
           contact aerators (as used in aerated lagoons)
Chlorination
Oxidation ponds

Disinfection

Chlorination
Ozone

Advanced Waste Treatment

Chemical/physical treatment methods
Carbon absorption
Ammonia stripping
Electrodialysis
Reverse osmosis or desalting
Microscreening

Ultimate Wastewater Disposal

Discharge into receiving waters
Irrigation or disposal on land by
- a. Application to surface
- b. Subsurface irrigation
- c. Groundwater recharge

Treat by advanced treatment system and reuse for industrial water supply or possibly a fire protection system

Treatment and Disposal of Wastewater Solids

Screenings

- a. Treatment
  - (1) Medium - shred and digest
  - (2) Fine - digest
- b. Disposal
  - (1) Medium - burial or incineration
  - (2) Fine - burial or incineration

Settled Solids (sludges)

- a. Treatment
  - (1) Sludges from primary and secondary treatment by:
    - (a) Digestion
    - (b) Thickening (by gravity or flotation; may or may not be conditioned by elutriation or chemicals)
      - 1) Vacuum filtration
      - 2) Drying on beds or in kilns
      - 3) Centrifugation
- b. Disposal
  - (1) Wet sludges - dumping at sea or piping to sea (where still permitted)
  - (2) Dried or dewatered sludges - incineration or use as soil conditioner or deposit in a landfill

Performance of Treatment Systems

Table A-2 is a classification matrix of treatment systems by their unit operations, removal efficiencies and expected effluent quality. It indicates the percentage removal of constituents (based on process effluent to process influent) and ranges of effluents of treatment systems which are employed in the wastewater treatment. Most of the systems shown have some form of pretreatment, in combination with primary, secondary or advanced, unit operation which would provide the influent quality that can be handled by the treatment system. In order for plants to approach the effluent ranges indicated, each unit operation would have to be examined and evaluated to determine what operation could be improved without affecting other plant operations.

UNIT OPERATIONS PRIMARY ②								SECONDARY			ADVANCED				TREATMENT SYSTEM	EFFLUENT CONSTITUENTS NOTE: Data in each box - top numbers in %, bottom in mg/l											MANUAL SECTION
Racks or Bar Screens	Medium Screens	Grit Chambers	Aeration	Pre-/Final Chlorination	Fine Screens	Chemical Precipitation	Primary Sedimentation	Biological Treatment	Final Clarification	Chlorination	Physical-Chemical	Sand Filtration	Carbon Adsorption	Sludge Treatment & Disposal		BOD	COD	Total Nitrogen	Ammonia Nitrogen	Nitrate Nitrogen	Total Phosphate	Suspended Solids	Color ③	Turbidity	Bacteria	Background Op Data Problems
■	■	■	■	■	■	■	■			■					PRIMARY TREATMENT	35-65 ④						45-75				C-1 to C-12 II-19 IV 62-63
															ACTIVATED SLUDGE											D-7 to D-9 II-22 IV 64-71
■	■	■	■	■	■	■	■	■	■	■					. Conventional	80-95 20-30										
■	■	■	■	■	■	■	■	■	■	■					. Contact Stabilization	85-95 20-25										
■	■	■	■	■	■	■	■	■	■	■					. Completely Mixed	80-95 20-20										
■	■	■	■	■	■	■	■	■	■	■					. Two Stage Activated Sludge	90-96 5-20										
															TRICKLING FILTERS											D-5 to D-6 II-21 IV 72-76
■	■	■	■	■	■	■	■	■	■	■					. Low Rate	85-90 25-30						85-90 20-30				
■	■	■	■	■	■	■	■	■	■	■					. High Rate	80-85 70-100						60-80 80-100				
															STABILIZATION PONDS											D-9 to D-12 II-22 IV 77-79
															PACKAGE AERATION PLANTS	88-99.5 6-22						74-94 17-29				D 13-14 II-21
															ADVANCED WASTE TREATMENT											E-1 to E-8 II-24 VI 83-88
■	■	■	■	■	■	■	■	■	■	■	■	■	■		. Reverse Osmosis	90 <5	90-98 <5	70 <5	60-85 <4	50-80 <4	90-99 0.5	100 0	100 0	80-100 -		
■	■	■	■	■	■	■	■	■	■	■					. Activated Carbon	90 <20	95 <20						90 <5	80 -		
■	■	■	■	■	■	■	■	■	■	■					. Microscreening	30-70 <10						60-80 <7				
■	■	■	■	■	■	■	■	■	■	■					. Deep Bed Sand Filtration (Rapid sand filtration)	50-70						20-80 3-5				
				■	■	■									. Phosphorous Removal (Chemical treatment)	35-65					70-85 2-4	60-85				
By Ammonia Stripping Tower															. Ammonia Stripping ①				80-95 <2							
■	■	■	■	■	■	■	■	■	■	■					. Electrodialysis	<20	<20			<5	<5	<2				

①A function of pH and temperature

②Not all operations are used in all plants

③In color units

④All percent removals are based on process effluent to process influent

Table A-2

Classification Matrix of Treatment Systems
by Their Unit Operations, Removal Efficiencies
and Effluent Quality

Appendix B

PERSONNEL REQUIREMENTS

This section of the manual contains information on personnel requirements for effective treatment plant operation. It lists the minimum skills required for the various duties which are performed at treatment plants. A manpower and work schedule is included to delineate the numbers of personnel and hours needed to perform the required work.

Table A-1 (Appendix A) of this manual indicates the classification of operator for plant size and treatment system. This data, along with the information presented in this section, should be compared against personnel information for the plant being evaluated to see if adequate staff (both in numbers and qualifications) is being utilized. This should be included in the overall evaluation rating given to the plant.

GENERAL SKILLS

The skill requirements outlined below are minimal for successful performance of specific required duties. These are only a guide; additional requirements for the particular plant location should be checked.

- Supervisory Personnel (level of ability depends on size and type of plant) - high school education or equivalent, should display better than average ability to:

    1. Use and manipulate basic arithmetic and geometry.
    2. Think in terms of general chemistry and physical sciences.
    3. Understand biological and biochemical actions.
    4. Grasp meaning of written communications.
    5. Express thoughts clearly and effectively, both verbally and in writing.

In addition, supervisory personnel are often responsible for:

1. Public relations
2. Bookkeeping
3. Analysis and presentation of data
4. Budget requests
5. Report writing
6. Personnel

7. Safety educational program
8. Contracts, specifications and codes
9. Estimates and costs
10. Plant library

- Laboratory Technicians - require training in laboratory procedures and mathematics

- Operating Personnel - require training in:
  1. Fundamentals of wastewater treatment processes, including chemistry and biology.
  2. Mathematics (including geometry).

- Maintenance Personnel - must be familiar with and capable of:
  1. Mechanical repairs
  2. Electrical and electronic repairs.

MANPOWER AND WORK SCHEDULING

- Day-Shift Operators. 225 days/year at 6 hours/day = 1,350 hours/year. Attempts to schedule workloads and staff plants on this basis indicates that 5-1/2 hours/day is more realistic. This value will drop as the number of phone calls, visitors, inspectors, and emergencies increase.

- Night-Shift Operators. 7 hours/man/shift (fewer interruptions and work is of the routine inspection and recording nature).

Table B-1 shows ranges of the number of personnel which would be required to operate various modes of treatment systems. Each plant may have its own particular operating mode, depending on the number of components which make up liquid and sludge treatment, along with administrative and general plant functions. The advanced waste treatment plants were not included in this table because of the lack of reliable manpower estimates for this classification.

Table B-1

PLANT MANPOWER REQUIREMENTS*

Type of Plant	Average Capacity (MGD)									
	1	3	5	10	20	35	50	65	80	100
Primary	4.5-6	6.5-7.5	7.5-9	10-13	15.5-19	22-27	29-34	34-41	40-49	50-59
Secondary (including Trickling Filter)	6-7	7.5-9.5	9.5-11.5	13-16	19.5-24	28-34	37-44	45-53	53-61	63.5-76.5
Secondary (including Activated Sludge)	7-8	9.5-10.5	11.5-13	15-18	23-26	33-38	43-49	51-59	61-69	71-82

*Based on a preliminary study performed by Black and Veatch for the EPA.

Appendix C

PRIMARY TREATMENT MODE
(Background Information)

This section of the manual contains background information on processes generally used in preliminary and primary treatment of wastewater. It describes the basic mechanisms of the various processes and how they fit into the overall treatment scheme. A list of references for each process is included for additional information.

The tables located in Section II of this manual list the common preliminary and primary treatment operating parameters, loading rates, material accumulated during process operation, and support systems which are used in conjunction with each process. If a general review of preliminary and/or primary treatment is desired, review this section plus the applicable tables in Section II, and the pertinent problems and solutions in Section IV.

GENERAL

Pretreatment of raw wastewater includes the removal of large pieces of debris by passing it through a bar screen to remove large solids and then a grinder (comminution) to reduce particle size of the remaining solids to protect plant equipment and prevent plugging of pipes. This treatment also includes degritting by sedimentation. After degritting, the wastewater goes to the primary treatment where a sedimentation process removes a portion of the suspended solids (SS) and the settleable solids, along with related biochemical oxygen demand (BOD).

Figure C-1 shows a pre- and primary treatment system. There are many configurations that can be representative of this form of treatment, with units being added or deleted on the basis of the degree of treatment required, economics and space availability.

References shown after each description of a process provide additional information on that particular process.

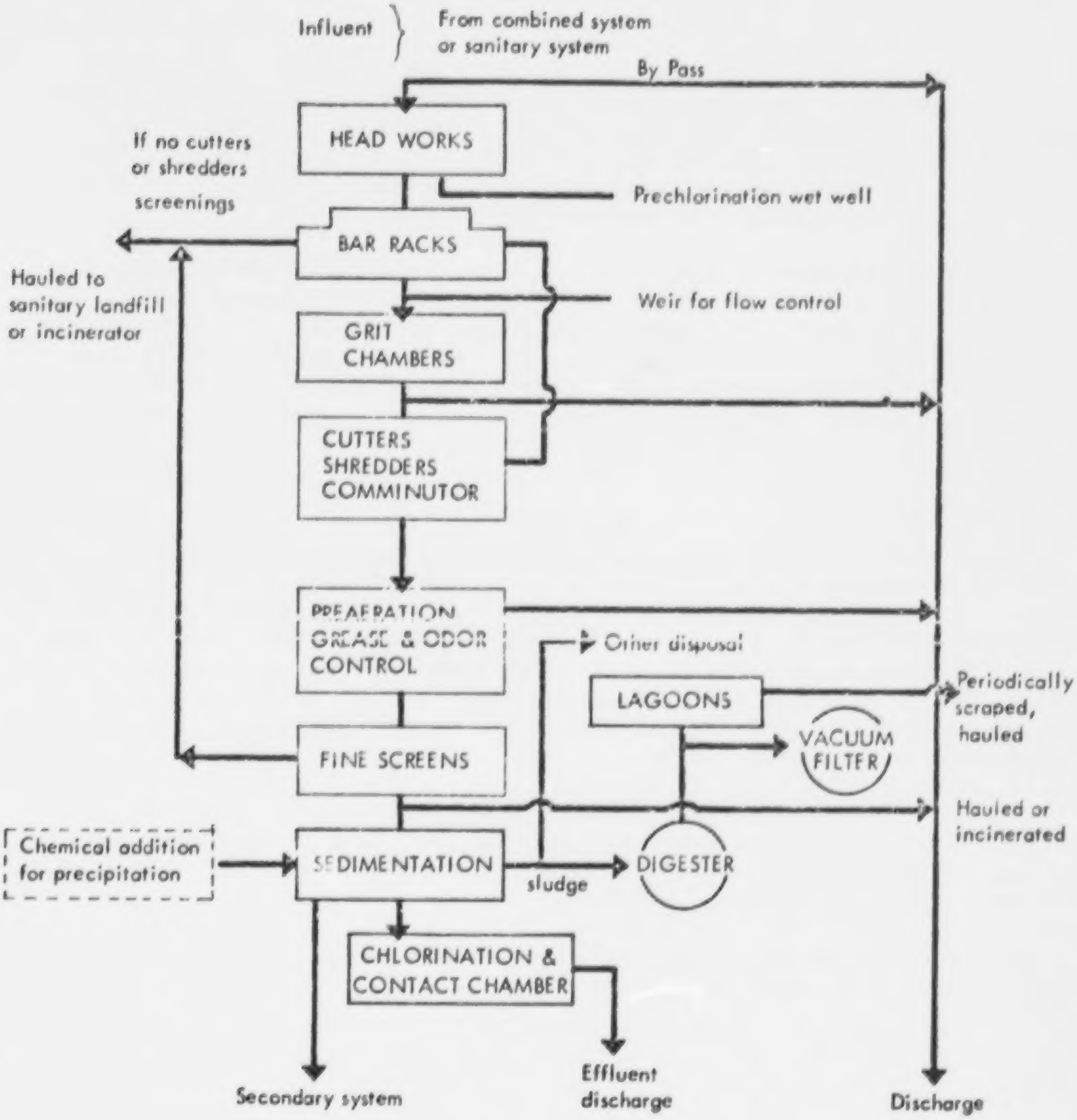

Influent
From combined system or sanitary system
By Pass
HEAD WORKS
If no cutters or shredders screenings
Prechlorination wet well
BAR RACKS
Hauled to sanitary landfill or incinerator
Weir for flow control
GRIT CHAMBERS
CUTTERS SHREDDERS COMMINUTOR
PREAERATION GREASE & ODOR CONTROL
Other disposal
LAGOONS
Periodically scraped, hauled
VACUUM FILTER
FINE SCREENS
Hauled or incinerated
Chemical addition for precipitation
SEDIMENTATION
sludge
DIGESTER
CHLORINATION & CONTACT CHAMBER
Secondary system
Effluent discharge
Discharge

Fig. C-1. A Primary Treatment System

PRETREATMENT

Flow Regulators

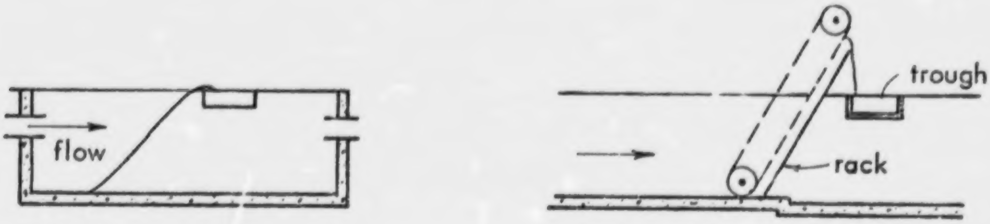
Local conditions will determine the hourly variations in quantity and strength of the wastewater. The regulation and metering of flow through the treatment plant is accomplished by use of weirs and flumes for open channel sections, and the venturi tube, orifice plate, Dahl flow tube and magnetic flow meter for pipe flows.

Devices which measure flow in an open channel all operate with a head loss. The parashall flume has the smallest head loss of all the commonly used open channel flow meters and is the one commonly used. Some plants utilize electronic sensors coupled with servo control units that operate valves or other mechanisms for flow control or diversion to various parallel units.

Racks and Screening Devices

Racks and screens are designed to remove floating matter and large suspended solids (mainly inorganic). Commonly used screening systems include racks, coarse or medium, having either:

1. Fixed bars, either hand or mechanically cleaned, or
2. Movable racks, such as the cage rack.



a) Fixed Bar Rack

b) Mechanically Cleaned Rack

Fig. C-2. Fixed Bar Racks

Figure C-2a shows a cross-section of a fixed medium bar rack. This rack, like the coarse rack, is primarily used to protect pumps. The medium rack also removes floating material which will form a heavy and troublesome scum in sedimentation basins.

For additional information see:

Chapter 4 of ASCE Sewage Treatment Plant Design and Chapter 22 of Water Supply and Sewage-Steel.

Grit Chambers

Grit chambers are installed prior to sedimentation and usually after bar racks to remove dense mineral matter such as sand, gravel, egg shells or cinders. Grit removal helps prevent problems in pumping sludge. Grit chambers are also used to avoid the cementing effects on the bottom of the sludge digester and in the sludge blanket of the primary settling tank. They also are installed to prevent reduction of active digester capacity and help prevent damage to mechanical equipment. These units are usually installed in plants with combined flow; however, many of the newer plants are designed with grit removal systems as common practice. Figure C-3 shows a plan and a section view of the most common configuration of a grit chamber.

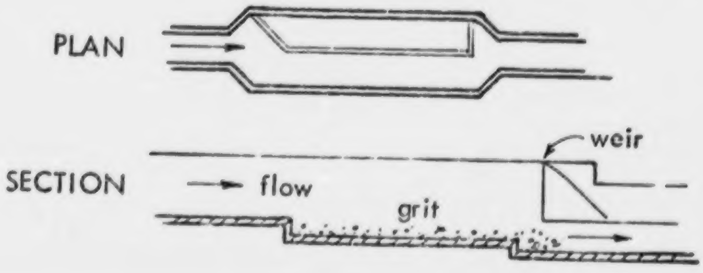


Fig. C-3. Grit Chamber

Removal mechanisms generally fall into one of four types:

1. Flow rate control which is maintained at 0.75 to 1.0 ft/sec by proportional weirs, by controlling the depth of flow.
2. Clarifier-like mechanisms, sized to cause grit to fall out. The grit is then cleaned by washing and the organics are returned to the wastewater flow.
3. Hydraulic cyclone, removes grit by centrifugal force which tends to force the heavier grit particles to the outside of rotating flow stream.
4. Injection of diffused air produces a spiral flow velocity causing particles to settle out.

The average cleaning interval is every two weeks. In wet weather, and particularly with combined wastewater flow, the accumulation of grit may be enormously increased, necessitating rapid or continuous cleaning to keep the unit operating efficiently.

For additional information see:

Ch. 23 of Steel; Ch. 4 of Imhoff-Fair; and ASCE Sewage Treatment Plant Design, Ch. 5.

Cutters, Shredders (comminutors)

Cutters and shredders are usually located after grit removal to prevent excessive wear on cutting edges and before the sedimentation unit so the shredded particles can be added back to the wastewater treatment stream and removed by sedimentation. Generally, fine racks and fine screens have been replaced by the cutting screens of communutors. These units are found in a variety of sizes, capacities, and configurations. Those include up and down moving cutting edges on bar racks and units that function like a kitchen sink garbage disposal with rotating cutter edges.

For additional information see:

Ch. 22 of Steel; Ch. 3 of Imhoff-Fair.

Fine Screens

Fine screens are used in old plants where cutters and comminutors were not installed and in newer plants as partial treatment of certain industrial wastes (e.g., cannery, brewery, distillery or packing house). They are usually located after the grit and pre-aeration units and before the sedimentation unit.

Fine screens may be made up of a series of disk screens with a frustum of a cone superimposed upon it. It rotates slowly, with brushes sweeping the screenings from the part above the wastewater flow to a conveyor belt or hopper. Drum screens are of several types. Basically, screenings are accumulated on the outside of a drum as it rotates or on the inside of a drum as the flow passes through. Conveyors and collectors then handle the retained solids.

For additional information, see:

Ch. 22, Steel; Ch. 3, Imhoff-Fair; Ch. 4, ASCE Sewage Treatment Plant Design.

Aeration and Chlorination

Aeration and chlorination are utilized to minimize odor and grease problems. Chlorine added to wastewater causes grease to coagulate. This process also reduces the finely divided suspended solids load on the primary sedimentation and biological treatment units. The cohesive force of the wastewater is reduced by the diffused air bubbles that buoy up the grease and suspended solids which are then skimmed off. This unit may follow the grit chamber and cutters. It usually precedes the fine screens and/or primary sedimentation unit.

For additional information, see:

Ch. 20, Fair & Geyer; Ch. 6, ASCE Sewage Treatment Plant Design; Ch. 3, Imhoff-Fair.

Sedimentation

Sedimentation (in primary treatment) usually follows grit removal, screening and pre-aeration. It precedes final chlorination and/or discharge to the receiving waters or other effluent disposal areas. It reduces the suspended solids and organic loading on subsequent secondary and advanced waste treatment units.

Sedimentation tanks may be constructed with or without mechanical devices for continuous removal of sludge. Tanks are classified by

- Primary - in which raw wastewater is settled
- Secondary of Final - in which mixed liquors or activated sludge plants or trickling filter effluents are clarified

- Intermediate - when used between filters in a two-stage trickling filter plant
- Septic tanks - combine sedimentation and sludge digestion in the same compartment
- Imhoff tanks (two-story tanks) - combine sedimentation and sludge digestion but are designed so that the processes are carried on in separate compartments arranged one above the other

Municipal wastewater contains both granular and flocculent solids. Based on this condition, the required capacity of primary settling tanks is both a function of surface loading and of volume loading or detention period.

A number of factors affect the performance of sedimentation tanks and the designs are influenced by those parameters which have the greatest impact on the desired results. Some of the commonly considered parameters are:

- Variation from 16-hour average flow
- Temperature variation (of the wastewater, as it affects the density and viscosity of the liquid)
- Density currents
- Solids concentration
- Solids removal

The mechanism of sedimentation is based on the settling velocity of particles. A particle in a still fluid of less density will move vertically downward because of gravity. The time required for the optimum percentage of these particles to drop out is the theoretical detention time of the settling basin. This time varies with what the next treatment mode is. Fig. C-4 shows the removal of suspended solids and BOD from wastewater in primary settling tanks (after Imhoff and Fair) as it varies with detention time. A secondary mechanism affecting the performance of the sedimentation tank is its overflow rate. A case in point is a high overflow rate with overflow velocities which exhibit a high scouring and solids-carrying capacity in wastewater effluent. The allowable values of overflow rates are dependent on the next mode of treatment.

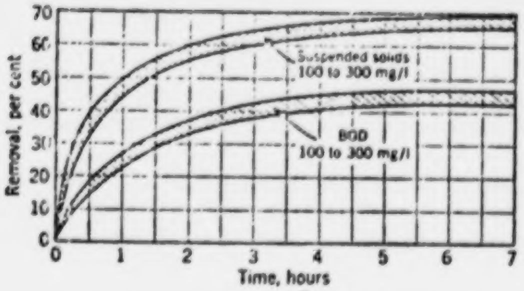


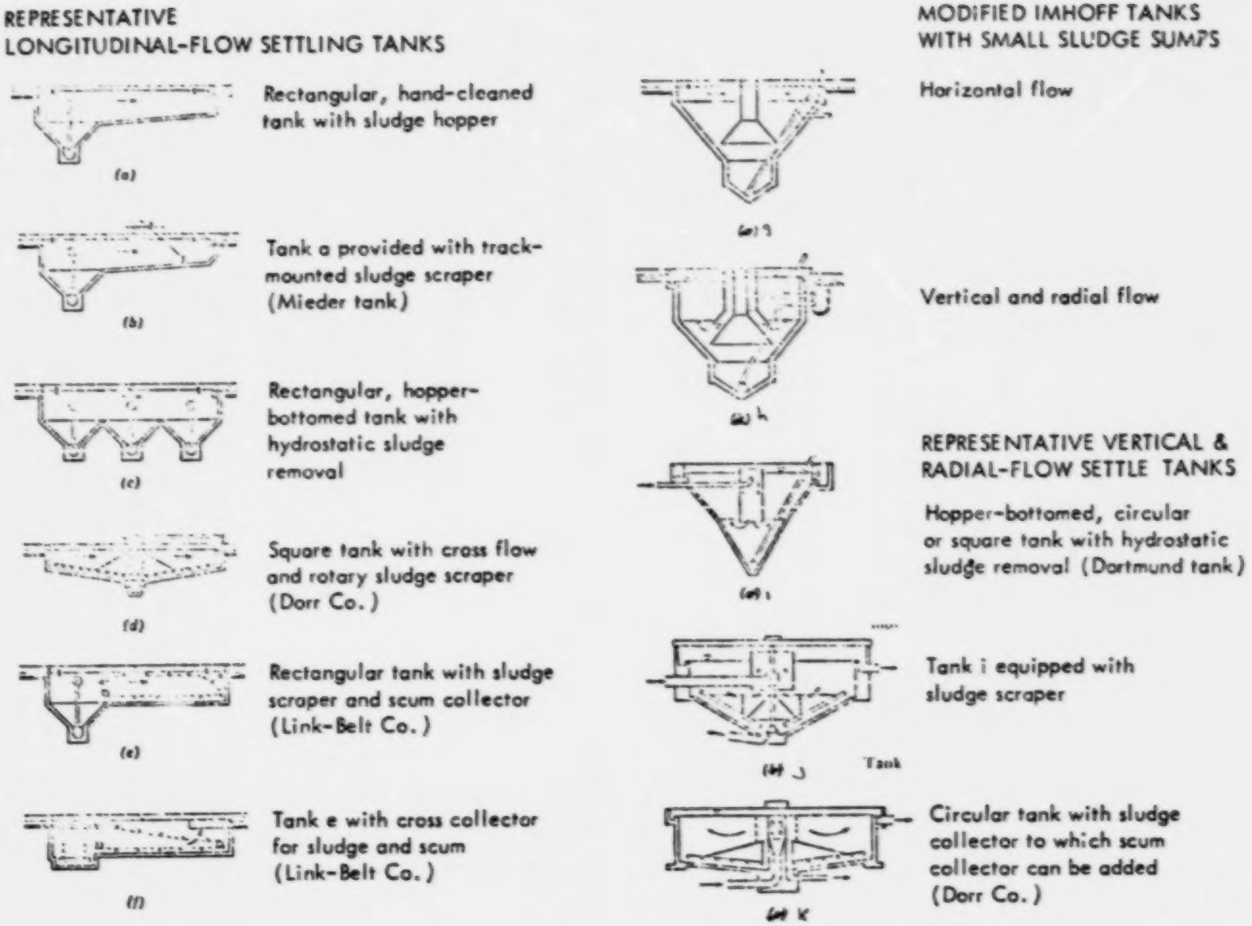
Fig. C-4. Percent of Suspend Solids and BOD_5

Both of these mechanisms are influenced by changes in the temperature of the wastewater. By increasing the temperature, it reduces the viscosity and density of the fluid, thereby increasing the settling velocity of the particles and reducing the detention time required. Along with this, characteristics of effluent quality over the overflow weir would be changed.

Figure C-5 shows the various types of sedimentation tanks and their sludge collection systems.

For additional information, see:

URS Project 7032; Ch. 9 & 23, Steel; Ch. 4, Imhoff-Fair; Ch. 3, ASCE Sewage Treatment Plant Design.



REPRESENTATIVE LONGITUDINAL-FLOW SETTLING TANKS

(a) Rectangular, hand-cleaned tank with sludge hopper

(b) Tank a provided with track-mounted sludge scraper (Mieder tank)

(c) Rectangular, hopper-bottomed tank with hydrostatic sludge removal

(d) Square tank with cross flow and rotary sludge scraper (Dorr Co.)

(e) Rectangular tank with sludge scraper and scum collector (Link-Belt Co.)

(f) Tank e with cross collector for sludge and scum (Link-Belt Co.)

MODIFIED IMHOFF TANKS WITH SMALL SLUDGE SUMPS

(g) Horizontal flow

(h) Vertical and radial flow

REPRESENTATIVE VERTICAL & RADIAL-FLOW SETTLE TANKS

(i) Hopper-bottomed, circular or square tank with hydrostatic sludge removal (Dortmund tank)

(j) Tank i equipped with sludge scraper

(k) Circular tank with sludge collector to which scum collector can be added (Dorr Co.)

Fig. C-5. Settling Tanks

CHEMICAL PRECIPITATION

Chemical precipitation processes obtain effluent quality which is in the range between primary sedimentation and the biological oxidation processes. The most effective use of chemical precipitation is under the conditions of seasonal variations in volume, strength or degree of treatment required of the wastewater. In plants that are not specifically designed for chemical precipitation, it is not uncommon for chemicals to be added prior to primary or secondary sedimentation to aid in the settling process.

The process of chemical precipitation functions under one of three mechanisms or under all three at the same time:

- Mechanical entrapment - heavy metal salts (such as alum or ferric chloride), plus an alkaline material, produce large volumes of precipitates which settle out true and colloidal suspension in wastewater
- Particle charge - colloidal particles with electrical charges, plus chemicals with opposite charges (polyelectrolytes), neutralize each other and settle out
- Physical - insoluble chemicals (such as activated carbon) with large surface areas either absorb or act as nuclei for the colloids and start settling

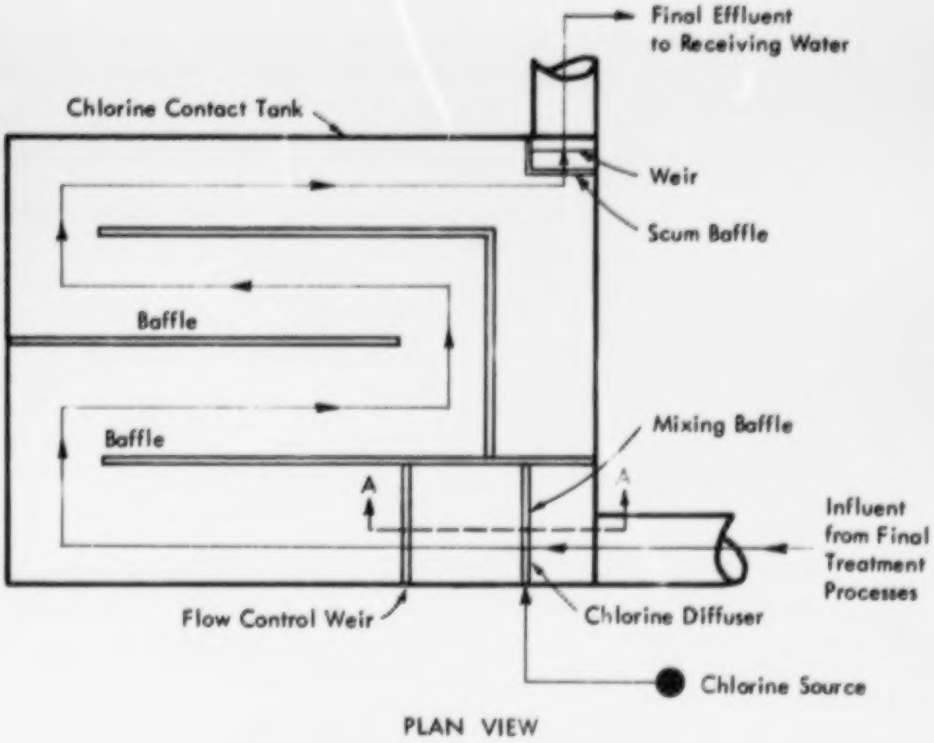
As in primary sedimentation, detention time under quiescent conditions is an important part of the processes, with detention times similar to primary sedimentation.

For additional information, see:

Ch. 9, ASCE Sewage Treatment
Plant Design; Ch. 9 & 23, Steel.

CHLORINATION

Final chlorination is used to disinfect (destroy the pathogenic organisms harmful to man or animals) treated effluents before they are discharged to the final receiving waters. To accomplish disinfection, enough chlorine is added to satisfy the chlorine demand of the waste while leaving a chlorine residual to destroy the pathogenic organisms. The amount of chlorine required for disinfection is largely dependent upon the organic matter present. The performance of the chlorination process is affected by the quantity of chlorine used, waste characteristics, where the chlorine is applied and how well it is mixed. The contact chamber should have a cleaning and flushing system to prevent buildup of sludge due to solids carry-over from the final settling tank and grease. Figure C-6 shows a typical baffled


Final Effluent to Receiving Water
Chlorine Contact Tank
Weir
Scum Baffle
Baffle
Baffle
Mixing Baffle
A
A
Influent from Final Treatment Processes
Flow Control Weir
Chlorine Diffuser
Chlorine Source
PLAN VIEW

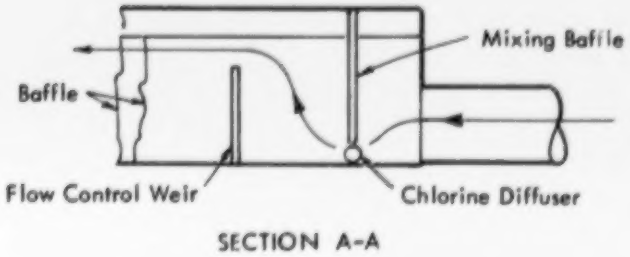

Mixing Baffle
Baffle
Flow Control Weir
Chlorine Diffuser
SECTION A-A

Fig. C-6. Final Chlorination System

chamber. To be most effective, the contact time should be not less than 15 minutes at maximum flow.

There are some State health departments which require a residual of 2.0 mg/l after 15 minutes. All such requirements should be checked before plants are inspected.

There is a secondary benefit of proper effluent chlorination. At the point where orthatoline residual is produced, each mg/l of chlorine absorbed will satisfy and remove approximately 2 mg/l of BOD_5 in the treated effluent.

Appendix D

SECONDARY TREATMENT

This section of the manual contains background information on processes now being used in the secondary treatment process of wastewater. It delineates the basic biological mechanism which takes place in the various biological reactors, a description of these reactions and how they fit into the treatment scheme, and a list of references for each process for additional information.

The tables located in Section II of this manual list the common secondary treatment operating parameters, loading rates, and support systems which are used in conjunction with each process. This information, along with this section and the common problems and solutions for secondary treatment (Section IV of this manual), should be reviewed for a general background to expedite the plant evaluation and help in finding solutions to process problems in this area.

As in pre- and primary treatment, there are many configurations that can be representative of secondary treatment. The unit operations which are shown in Figure D-1 make up the basic secondary mode of treatment.

In secondary treatment, flow is received from the primary treatment system. This flow then enters a biological reactor where biological growth occurs. This growth "fixes" most of the remaining organic materials in a biological mass (biomass). This biomass is then removed by sedimentation in the secondary clarifier. Some of the sludge (settled biomass) is returned to the inlet of the biological reactor and is mixed with the incoming primary effluent so that organisms with increased assimilation capacities can work on the waste. The effluent from the secondary clarifier is then chlorinated and discharged to the receiving body.

The biological reactors which are in common use in wastewater treatment were listed in Appendix A of this manual. They can be operated in many modes, depending on plant area limitations or treatment desirability. In many cases the only prior requirement to the use of a biological reactor is primary treatment.

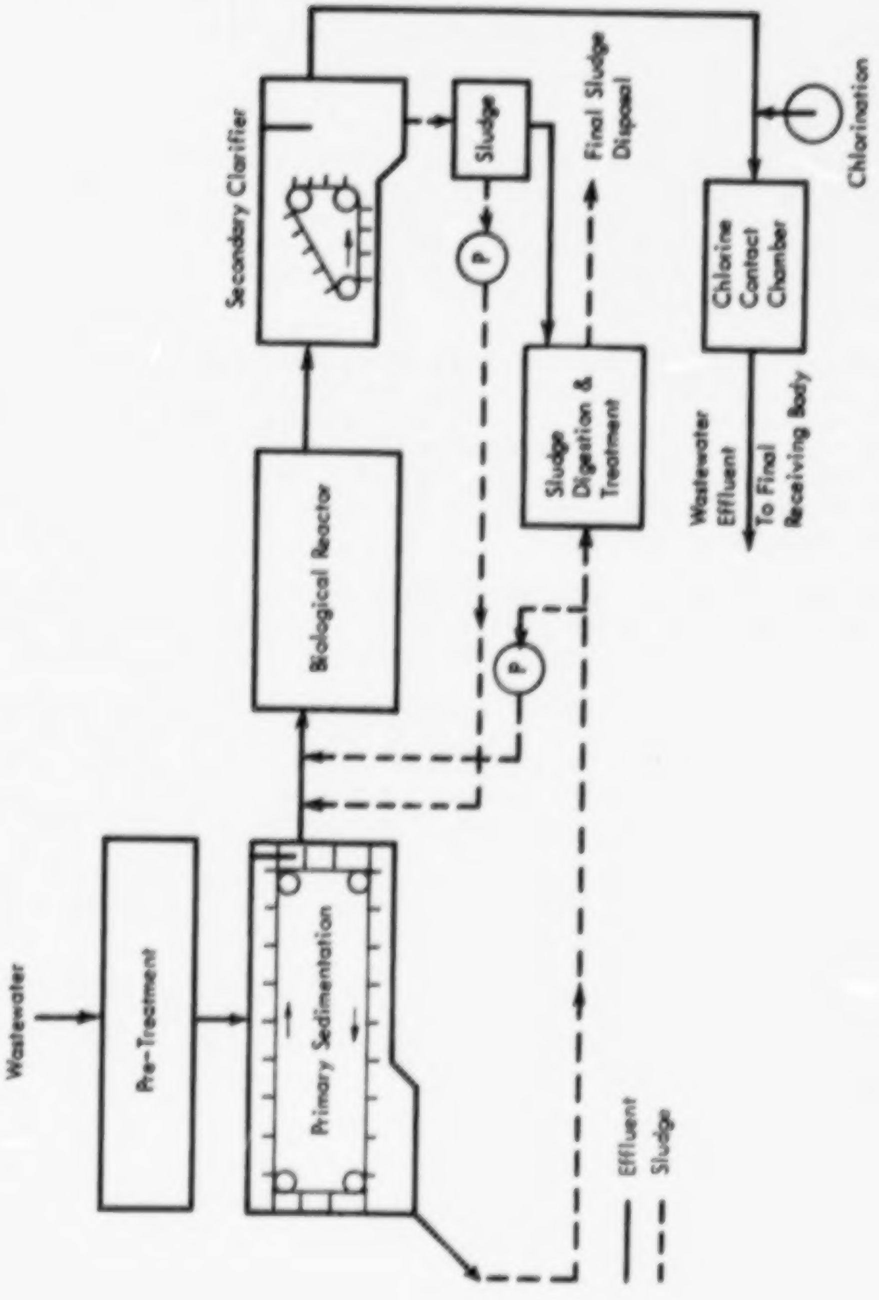

Wastewater
Pre-Treatment
Primary Sedimentation
Biological Reactor
Secondary Clarifier
Sludge
P
P
Sludge Digestion & Treatment
Final Sludge Disposal
Chlorine Contact Chamber
Chlorination
Wastewater Effluent
To Final Receiving Body
Effluent
Sludge

Fig. D-1. Flow Diagram of a Secondary Treatment System

GENERAL BACKGROUND ON A BIOLOGICAL REACTOR

In nature, bacteria and other microorganisms break down organic materials (the substrate) found in wastewater into simple, more stable substances. A biological (aerobic) reactor provides a place where organic waste is brought into contact with the surface, contact, or interfacial forces of biological slimes, or films, zoogleal aggregates, activated sludges or activated surfaces to remove suspended and finely divided solids and dissolved organic matter by the mechanisms of adsorption and coagulation, and enzyme complexing. Whatever the individual operation of the biological reactor, the microorganisms which stabilize the wastewater must have a continuous supply of substrate (food), an adequate supply of oxygen (aerobic systems only) and a suitable supporting film of floc.

The reactions involved in the reduction of organic material in the wastewater during biological oxidation can be interpreted as a three-phase process:

1. an initial removal of BOD on the contact of a waste with a biologically active sludge or film which is stored in the cells of the organism as a reserve food source
2. removal of BOD in direct proportion to biological sludge or film growth
3. oxidation of biological cellular material through endogenous respiration.

For additional information, see:

Ch. 2, Eckenfelder & O'Connor;
Ch. 1, Rich Unit Process;
Ch. 6, Imhoff-Fair.

TRICKLING FILTERS

A trickling filter is a fixed bed system over which wastewater is intermittently or continuously discharged and contacted with biological films on the filter media. Through this contact nonsettleable suspended matter and colloidal and dissolved organic matter are removed from settled wastewater by the organisms to be used as food.

A schematic representation of mechanism involved in the trickling filter processes is shown in Figure D-2. The largest portion of the wastewater applied to the surface of the filter passes rapidly through the filter, and the remainder slowly trickles over the surface of the slime growth. The reduction of organic loading occurs in two stages:

- the wastewater passes rapidly through the filter and removal occurs by biosorption and coagulation
- soluble constituents are removed from the remaining portion of flow due to the substrate utilization by the organisms.

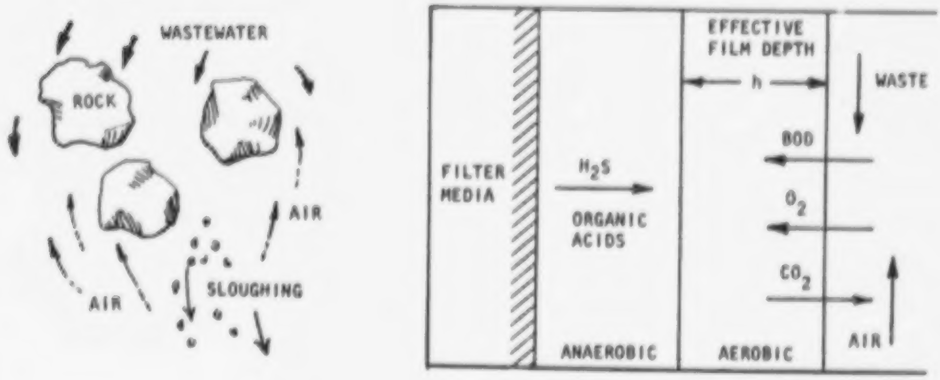

WASTEWATER
ROCK
AIR
SLOUGHING
AIR
FILTER MEDIA
H_2S
ORGANIC ACIDS
ANAEROBIC
EFFECTIVE FILM DEPTH
h
AEROBIC
WASTE
BOD
O_2
CO_2
AIR

Fig. D-2. Trickling Filter

Classification of Trickling Filters

Filter classification is based on applied hydraulic and organic (BOD) loadings (Section II of this manual shows typical loading rates).

- Low-Rate (Standard or Conventional Filter) - Low-rate filters usually operate with intermittent dosing. The wastewater is applied to the filter surface and passes through the filter with its effluent going to the secondary clarifier without recirculation. The filter depth is usually greater than for high-rate filters.

- High-Rate - Wastewater is applied much in the same manner as in the low-rate filter. However, the hydraulic loading is five to fifteen times as great, with the organic loading being four to five times greater. Along with the higher loading rates, the high-rate filter is characterized by the recirculation of a portion of the wastewater.

- Roughing Filter - Roughing filters are used to reduce the organic load applied to subsequent filters of activated sludge units. They are designed on the basis of the volume of liquid applied to filter. They will also handle a greater organic loading than low- or high-rate filters, but with reduced removal efficiencies.

Trickling filters, like most biological reactors, are followed by a final sedimentation process to remove any biomass which is lost from the reactor. This final sedimentation process is figured in total process efficiency when it is calculated.

For additional information, see:

Ch. 6, Eckenfelder-O'Connor;
Ch. 24, Steel;
Ch. 6, Washington State Wastewater Plant Operation Manual;
WPCF Publication No. 14, Sec. 15, Ch. 11, ASCE Treatment Plant Design.

ACTIVATED SLUDGE

The activated sludge process is based on the utilization of a floc made up of microorganisms, non-living organic matter and inorganic materials. These are brought into contact with primary treated wastewater (in most cases) in the presence of dissolved oxygen. A high degree of mixing causes the removal of settleable solids, nonsettleable suspended solids, colloidal solids and dissolved organic matter.

The basic process flow includes:

- Aeration of pre-primary treated wastewater for a period of time
- Final clarification for the separation of solids and liquids at the end of the contact time
- The return of a percentage of the separated solids to the reactor for mixing with influent wastewater
- Discharge of the liquid wastewater fraction as process effluent.

Classification of Activated Sludge Processes

- Conventional (plug flow). All primary-treated wastewater is introduced at one end of the reactor along with the returned sludge. The length of the reactor is usually 5 times the width. The diffusers are located along one side of the tank so that the diffused air bubbles cause a circular rolling motion on an axis parallel to the length of the tank. This class of activated sludge process provides insufficient dissolved oxygen content at the influent part of the reactor.

- Modified (high-rate). This process utilizes short aeration periods and low activated sludge concentrations. It is characterized by low BOD removals (40-70) and a low percentage of sludge return (10%). Also associated with this process is a high solids accumulation due to insufficient time for significant oxidation of cellular mass and the retention of influent inerts.

- Step Aeration. Primary treated wastewater enters this reaction at a number of different points along one side of the reactor, but with the returned sludge being introduced at the point of first entry, with or without a portion of the incoming wastewater. The greatest concentration of sludge solids in the mixed liquid is where the final amount of waste is introduced and decreases as more waste is introduced at subsequent points. By entering the waste in this manner, a more uniform aeration of the waste occurs, and a decrease in detention time is possible.

- Tapered Separation. Basically the same concept as step aeration except that the air is added in stages along the reactor instead of the wastewater. The air requirements are staged to give maximum amount at the inlet of the raw waste with the rest regulated to meet oxygen utilization in other sections of the reactor. This process is supposed to provide better control in meeting shock loadings.

- Kraus Process. This is a modification of conventional activated sludge where incoming wastewater (primary treated water) has insufficient amount of nutrients (usually nitrogen) available to provide a stable activated sludge process. These nutrients are provided by the recycling of digester mixed liquor to the activated sludge system by means of a nitrification tank where a mixture of supernatant and returned activated sludge is aerated 24 hours and returned to the activated sludge unit. Aside from supplying the needed nutrients, there are other beneficial effects from this process: it provides an oxygen reserve in the form of nitrates and also tends to weight the sludge thus providing better settling characteristics.

- Completely Mixed Reactor. The primary treated waste is completely mixed throughout the reactor as quickly as possible. The process provides for immediate distribution for all incoming waste, and the oxygen requirement throughout the tank is uniform. This process minimizes the effect of slug loadings of very strong waste or short term, high volume wastes (shock loadings).

- Contact Stabilization. Incoming primary-treated wastes (some new plants omit primary sedimentation) are mixed with returned sludge in a contact basin for a period of 30 minutes to one hour in which most of the absorption of solids is accomplished. This short contact permits solubilization of the absorbed organic solids before the absorption by microorganisms in the activated sludge of the soluble organics. This process is also affected by a highly variable influent flow rate which reduces the adsorption time causing high effluent BOD.

- Two Stage Aeration. This is basically the same as contact stabilization except that the contact time is six times as long, providing enough time for absorption, solubilization, absorption and the synthesis of cellular material. The aeration time of the second reactor is long enough to provide for the oxidation of a large portion of the synthesized cell mass.

Extended Aeration. This type of system is usually provided for a small-sized treatment facility. This system is completely mixed with a low food/microorganisms (F/M) loading rate for a given population, which allows for almost complete oxidation of synthesized cell mass. It is also characterized by low oxygen uptake rate.

For additional information, see:

Ch. 2, 3 & 6, Eckenfelder-O'Connor;
Ch. 6, State of Washington Wastewater Plant Operators Manual;
Ch. 25, Steel;
Ch. 10, ASCE Sewage Treatment Plant Design.

STABILIZATION PONDS AND LAGOONS

The operation of stabilization ponds and lagoons that are aerobic depends on oxidation and reduction by microorganisms, sedimentation, bio-flocculation and anaerobic digestion of bottom sludge. The oxygen utilized in this process is obtained from the algae growth present or mechanical and diffused aerators with additional oxygenation being provided by wind and wave action. Some ponds operate anaerobically in much the same way as a digester with sufficient depth to create anaerobic conditions due to poor oxygen transfer to the deep parts of the pond.

The effluent from this treatment process is disposed of by percolation (where ground water regulations permit), evaporation, transpiration from irrigation of cover crops or discharged to a receiving body.

Classification of Stabilization Ponds and Lagoons

The classification of stabilization ponds and lagoons may be according to: depth, main source of oxygen, rate of waste loadings (lb of BOD per acre per day), inlet, flow-through, and inlet and outlet arrangements including load distribution, recirculation, and effluent disposal. In general, stabilization ponds and lagoons may be classified into three types:

- Large Holding Reservoirs. These are characterized by long detention times (months, usually) with the oxygen being supplied by surface aeration and dilution of the wastewater with clean water. The removal of organics is accomplished by bio-flocculation, oxidation, and reduction with an aerobic digestion of bottom sludge taking place.

- Stabilization Ponds. The rate of oxidation of organic matter by microorganisms exceeds the rate of natural surface aeration and the algal growths must supply the additional oxygen required. Since solar energy is required for photosynthesis, the depth of the ponds is limited. Location is also a limiting factor as climatic parameters are very important. The detention times in stabilization ponds range from less than a week up to six weeks, depending on the type.
    a. Facultative Ponds. This type of pond is characterized by the aerobic and anaerobic processes occurring simultaneously. The removal of organic material is accomplished by sedimentation, bio-flocculation and aerobic oxidation. The primary source of oxygen is obtained from algae growth with a second source supplied by wind and wave action.
    b. High Rate Ponds. This pond is characterized by its shallow depths for extreme solar energy penetration; it is fully mixed and completely aerobic. The organics in this system are oxidized by microorganisms utilizing oxygen generated by algal growths.
- Aerated Lagoon. This system is characterized by the use of mechanical aeration to supply the required oxygen supply directly, causing sufficient mixing to supply additional oxygen from surface aeration, so that the lagoon remains aerobic.

For additional information, see:

Ch. 6, Eckenfelder-O'Connor;
Ch. 12, ASCE STP Design
Ch. 21, Steel.

INTERMITTENT SAND FILTERS

Intermittent sand filters are being phased out of secondary waste treatment mode due to the large area requirements. Because of the high quality effluent produced, they may be used in advanced waste treatment modes on a smaller scale to polish secondary treatment effluent.

The basic mechanism of this process is a straining effect produced by sand grains which trap suspended solids. The intermittent dosing (twice during a 24-hr period) permits air to enter the bed to allow microorganisms to reduce the organic load aerobically. It should be noted that work done by Grantham, Emerson and Henry in Florida indicates that sand size affects the percentage of organic material removed.

For additional information, see:

Ch. 12, ASCE STP;
Ch. 24, Steel.

SECONDARY CLARIFICATION

This unit follows the biological reactor (such as the trickling filter of activated sludge). Its primary functions are to retain the biological growths produced by the reactor for recycling and to produce clarified liquid in the overflow and thickening on the bottom of the tank. This depends on the physical and chemical nature of the sludge and the hydraulic characteristics of the clarifier.

The clarifiers can be rectangular or circular in shape. In both types of clarifiers, their size is related to one of the following factors:

- Surface of clarifier area over the M.L.S.S. concentration
- Surface area and volume of clarifier for producing thickening and underflow of a desired concentration
- Volume for retention of settled sludge

Along with these requirements, the velocity of the density currents are critical in the clarifier. If these velocities are increased, the critical value for separation of solids could be exceeded causing bottom scour with the possibility of carryover of low density particles in the effluent.

For additional information, see:

Ch. 4, Rich, Unit Operations of Sanitary Engineering;
Ch. 5, Eckenfelder-O'Connor;
Paper by Clair Sawyer - Final Clarifiers, and Clarifier Mechanisms (MIT);
Ch. 8, ASCESTD.

PACKAGE AERATION PLANTS

This type of treatment system is characterized by

- low daily flow
- no primary sedimentation
- 20-24 hour aeration period
- long final sedimentation period
- limited flow control between processes due to close proximity of operations.

The basic mechanism of the process is to keep the microorganisms predominantly in the endogenous growth phase (organisms are using all material in absence of organic material growth) through long detention time and a low food-to-microorganism ratio in the aeration tank.

Two systems in common use consist of:

- aeration tank and final sedimentation tank plus chlorination
- mixing chambers, sedimentation tank, and sludge reaeration tank plus chlorination.

Both of the systems utilize aerated digestion of the activated sludge. Critical to successful operation of these plants is a program of effective solids removal from the system.

For additional information, see:

"Aeration Plant in Florida", ASCE Jour. of Sanitary Eng., Vol. 88;

"Field Evaluation of the Performance of Extended Aeration Plant", J. WPCF, Vol. 41, July 1969, p. 1299.

Appendix E

ADVANCED WASTEWATER TREATMENT

Advanced wastewater treatment processes are described in this section of the manual. It delineates how the process works, the various organic and inorganic constituents which are removed by the processes, removal percentages which can be expected, and references for additional information.

The tables in Section II of this manual list the common advanced waste treatment operating parameters, a range of materials accumulated due to process operation, and support systems which are used in conjunction with each process. This operating information, together with the common problems and suggested solutions, should be reviewed with the information in this section to provide background data against which an advanced waste treatment plant can be evaluated.

GENERAL BACKGROUND

In the past few years the United States has experienced rapid population growth, concentration of people in urban areas, and the appearance of ever larger industrial establishments. All of these factors have contributed to increased pollutional loads on streams, rivers, and other receiving waters. The result has been that conventional primary and secondary treatment processes are not always able to provide adequate removal of pollutants. For this reason, advanced waste treatment processes have been developed to remove pollutants not handled by conventional (primary and secondary) treatment. Advanced waste treatment is intended, therefore, to alleviate pollution of a receiving watercourse. It may also, however, be used to provide a water quality adequate for reuse, since the population expansion and increased water demand mean that more and more people have water supplies that must be used more than once for industrial and domestic purposes.

It should be pointed out that certain materials to be removed by advanced waste treatment are normally removed to a great extent by secondary treatment (e.g., 90 to 95 percent of suspended solids are removed in an efficient secondary plant). Advanced waste treatment, which is important whenever upsets occur in such a secondary plant, is physical-chemical treatment. This process, due to its reliability, could also be used in cases where direct water reuse is anticipated and 90 to 95 percent removal is inadequate. Advanced waste treatment is more commonly used, however, for materials which are not efficiently removed by primary or secondary treatment (e.g., phosphates and nitrates).

In general, advanced waste treatment is applied to effluent from conventional secondary processes for the purpose of removing one or more of the following constituents: soluble organic compounds, soluble inorganic compounds (nitrogen and phosphorus), particulate solid material, and pathogenic organisms.

The following paragraphs examine selected advanced waste treatment unit operations to provide descriptions of the processes involved and present references of interest for additional detailed information.

CHEMICAL/PHYSICAL TREATMENT

Chemical precipitation and sedimentation is a treatment method combining chemical and physical elements to achieve removal of soluble inorganic compounds (such as phosphorus) or removal of suspended solids in a colloidal state. A mineral or synthetic polymer is added to the wastewater and chemically reacts with one or more constituents of the wastewater to produce a precipitant. This precipitant is then coagulated or flocculated by means of the mechanical action of mixing or the addition of a coagulation/flocculation aid. The precipitant is subsequently removed by sedimentation. In this process, constituents of the wastewater are removed in several ways:

- chemical reaction with the material added and sedimentation of the resulting precipitant
- physical capture of suspended solids by the descending precipitant
- adsorption of particles and dissolved constituents by the precipitant.

Removal of phosphorus is typically obtained by addition of calcium, aluminum, or iron salts (e.g., lime, alum or ferric chloride). Phosphorus removals vary from about 70 to 95 percent.

Chemical/physical treatment can be applied to secondary effluent or to primary effluent. In an activated sludge plant, efficient removals have been achieved by mineral addition before primary settling, after primary settling, in the aeration tank, or near the mixed liquor exit point. In a trickling filter plant, the precipitation is usually accomplished in the primary sedimentation tank. Final chlorination and discharge to receiving water follows chemical/physical treatment after it is used in secondary or advanced waste treatment.

Chemical/physical treatment is basically a sedimentation process and has associated with it the same type of equipment and performance parameters as in primary or secondary sedimentation. Additional equipment is, however, required to store and feed the required additional materials into the sedimentation tank. Specialized equipment and instrumentation are necessary since slurries often are involved and pH control is critical.

For additional information, see:

Ch. 2, Culp and Culp
Ch. 26, 29 and 30, Fair, Geyer and Okun
Advanced Waste Treatment Research Series AWTR-2, -12
Advanced Waste Treatment Seminar, Session II (Oct. 1970)

CARBON ADSORPTION

Carbon adsorption is a treatment method used to remove residual dissolved and suspended organic material from wastewater treatment plant effluents. These organic pollutants are typically responsible for the color, odor, taste, and froth problems of wastewater. In carbon adsorption, the wastewater is continuously run through a bed or column of activated carbon which removes the organic materials by adsorption. When the adsorption capacity of the columns is exhausted, the wastewater is rerouted through another bed of carbon and the exhausted carbon is regenerated for use again.

In actual plant experience (South Tahoe), the carbon adsorption process has yielded the influent entering it the following removals: BOD - 70+%; COD - 50+%; TOC - 75%; color - 75%. In pilot plant tests, removals of suspended solids have run up to 90% and removal efficiencies even greater than those shown above have been experienced.

Conventional primary and secondary treatment removes organic matter to a great extent. The difficult-to-remove organics (refractory organics) are handled by carbon adsorption. Carbon adsorption, therefore, follows secondary treatment and precedes chlorination.

The activated carbon must be of the proper type to adsorb materials present in the existing wastewater. Many different types are available, and the actual type and quantity to use depend on the kind and concentrations of pollutants to be removed. In addition to variations in the adsorption characteristics, activated carbon also varies in physical form from powdered to granular. Since the carbon is stressed during regeneration and transported between generations, it must be durable to such stresses and still maintain performance. The granular carbon is generally optimum from an overall cost performance, endurance, and recovery point of view.

The carbon columns may run from 8 to 12 ft in diameter and 24 to 60 ft tall. Usual operation is to run the wastewater through from two to four columns in series. The most important factors in column operation are contact time, pretreatment, and flow conditions within the column itself.

For regeneration, the spent carbon is transported from the column in water slurry and fed by screw conveyor into a regeneration furnace where intense heat burns off accumulated material, opening the interstices of carbon for additional adsorption. Makeup carbon is added as needed and the regenerated carbon is returned to the column (again in the slurry).

For additional information, see:

Ch. 7 and 8, Culp and Culp
Ch. 26, Fair, Geyer and Okun
Advanced Waste Treatment Research Series 9, 10, 11 and 16
Advanced Waste Treatment Seminar, Section III.

AMMONIA STRIPPING

Ammonia stripping is a treatment method for specific removal of nitrogen in the form of ammonia. The process is one in which the wastewater is cascaded down a stripping tower and air is forced up through the tower. The air strips the dissolved ammonia from the water and carries it off into the atmosphere. Removal efficiencies up to 90% have been achieved.

Neither conventional primary nor secondary treatment removes significant amounts of nitrogen, but the biological process does convert nitrogen compounds in the wastewater into ammonia. Ammonia stripping, therefore, follows secondary treatment and precedes chlorination.

Effective ammonia stripping requires a high pH and high air-to-liquid loadings. Both of these factors are temperature dependent, such that when air temperatures are lower, the corresponding pH and air loadings must be higher to give the same ammonia removal. Normal operation calls for a pH of above 11 and air rates of from 200 to 500 cfm/gpm.

Actual ammonia stripping towers are very similar to forced-draft type cooling towers. The pH adjustment takes place before entry of the wastewater to the stripping tower. In a typical operation, the pH adjustment, using lime and a phosphorus removal step, takes place in a clarifier just before feeding the wastewater to the stripping tower. After passage through the tower, recarbonation is performed to readjust pH as needed to prepare the wastewater for filtration, carbon adsorption, chlorination, or final discharge. In the recarbonation process, an intermediate reaction or settling basin exists between the two recarbonation basins. In the settling basin, a dense floc rich in calcium carbonate is formed, and this is a source of material to reclaim lime for reuse.

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In an advanced waste treatment scheme, therefore, the secondary effluent proceeds through a chemical/physical treatment for phosphorus removal, then ammonia stripping, carbon adsorption, and finally filtration and/or desalting.

Two problems that may occur with ammonia stripping are: 1) the inability to operate at air temperatures below 32°F; and 2) the deposition of calcium carbonate scale on stripping tower surfaces.

For additional information, see:

Ch. 4 and 5, Culp and Culp
Ch. 28 and 31, Fair, Geyer and Okun
Advanced Waste Treatment Seminar, Session 1.

ELECTRODIALYSIS

Electrodialysis is a membrane desalting process for removal of dissolved inorganic ions from wastewater. In the process, membranes are used which are permeable to charged ions and impermeable to ions of the opposite charge. A pair of opposite membranes has a direct current potential applied across them and the wastewater is pumped between them. Positive and negative ions, therefore, permeate out of the wastewater, and a product with lower dissolved minerals results. In addition, a brine stream very concentrated in dissolved minerals also results. Electrodialysis is capable of yielding product water with up to 85% of the total dissolved solids removed. In this process, nitrogen removal is about the same as total dissolved solids, but phosphorus and CO do not show the same high removal. A typical system will yield about three gallons of product water and one gallon of brine for every four gallons of feedwater treated.

Conventional primary and secondary treatment does not remove significant amounts of dissolved inorganics. Electrodialysis usually follows carbon adsorption which removes constituents capable of fouling the electrodialysis membranes (non-ionic particles).

Normal operation of electrodialysis requires pH control, chemical control of scale formation, and routine flushing and cleaning of membrane surfaces. Proper disposal of the brine stream is important and this may consist of ocean dumping (where it is still permitted), evaporation pond utilization, or deep well injection.

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For additional information, see:

Ch. 21 and 30, Fair, Geyer and Okun
Advanced Waste Treatment Seminar, Section IV.

REVERSE OSMOSIS

Reverse osmosis is a membrane desalting process for removal of dissolved inorganic materials from wastewater. In the process, membranes are used which are permeable to pure water, but nearly impermeable to dissolved salts when operated at high pressure. Product water with lower dissolved minerals is forced through the membrane, and a brine stream very concentrated in dissolved minerals is rejected by the membrane. Reverse osmosis is capable of yielding product water with up to 85% of the total dissolved solids removed. In this process, phosphorus, COD, and ammonia-type nitrogen are removed about as efficiently as the total dissolved solids, but nitrate-type nitrogen is less efficiently removed. A typical system will yield about three gallons of product water and one gallon of brine for every four gallons of feedwater treated.

Conventional primary and secondary treatment does not remove significant amounts of dissolved inorganics. Reverse osmosis usually follows carbon adsorption in an advanced waste treatment scheme so that fouling of membranes is avoided.

Normal operation of reverse osmosis requires pH control, chemical control of scale formation, and routine flushing and clearing of membrane surfaces. Proper disposal of the brine stream is important, and this may consist of ocean dumping, if still permitted, evaporation pond utilization, or deep well injection.

For additional information, see:

Ch. 21 and 30, Fair, Geyer and Okun
Ch. 10, Culp and Culp
Advanced Waste Treatment Seminar, Section IV.

Appendix F

SOLIDS TREATMENT AND DISPOSAL

This section of the manual supplies background information on the various processes involved in handling and treating of solids accumulated during the wastewater treatment process.

Sludges are characterized by their percentage water content, volatile matter, and the various processes by which they are produced. In addition, this section explains the methods available for final solids disposal. A comparison of operational parameters and loading rates (design specification) with those presented in this manual or in other sources will facilitate an evaluation of the solids treatment and disposal system. Deviations from normal will reveal any problem areas. A check of the common operating parameters, loading rates, and support systems which are generally used in solids handling (Tables II-5 and II-6 in Section II) should also be made. These tables, along with the common problems in solids handling (Section IV), and a review of this section will supply information needed for a general evaluation of the solids handling program carried on at the wastewater treatment plant.

GENERAL BACKGROUND

The solids accumulated from the various wastewater treatment processes can be grouped into one of two categories: those trapped on medium and fine screens in pretreatment, and those formed from processes in the primary, secondary and advanced treatment modes.

Large-size material trapped by racks, such as glass bottles, rags, or pieces of wood, is collected and usually buried in a sanitary landfill. The solids from medium screening are shredded and treated by anaerobic digestion, along with fine-screen solids.

Settled solids (from primary and secondary treatment) can be treated by combinations of thickening, anaerobic and aerobic digestion, conditioning elutriation; or with chemicals, vacuum filtration and drying on beds or in kilns.

The final disposal of wet sludge is accomplished by dumping or piping it to sea or by incineration; dried or dewatered sludges are also incinerated, used as soil conditioners, or buried in sanitary landfills.

TREATMENT OF SLUDGE

The water content of sludge is the controlling factor as to the volume of sludge produced. Sludge can be characterized by the type of process by which it was produced. The following table characterizes sludges produced by the various processes.

Table F-1

SLUDGE CHARACTERISTICS

Process Producing Sludge	Percent Water Content	Volatile Matter as Percentage of Dry Solids
Primary sedimentation sludge	94 - 96*	70
Activated sludge High rate	95 - 97.5	--
Trickling filter	96 - 97	45-70
Chemical precipitation	95	--
Digested sludge (well digested)		32-45
• Primary	88 - 94	
• Primary and activated	94 - 96	
• Primary and trickling filter	90 - 94	

* Steel, Water Supply and Sewage, pp. 574-575

The Digestion Process

Anaerobic organisms break down complex molecular structures of the solids and release much of the bound water, while obtaining nutrients and energy from the conversion of the raw solids into more stable organic and inorganic solids. Anaerobic sludge digestion takes place in three phases:

- Acid fermentation. Soluble or dissolved solids are broken down into simple organic acids (volatile acids) with a decrease of pH.

- Acid regression. The organic acids and nitrogenous compounds are decomposed with an increase in pH.
- Methane production. This occurs simultaneously with the first two phases. Methane bacteria reduce the organic acids and other products of the first and second phases to produce methane and carbon dioxide gases.

Sludge digestion accomplishes the following:

- Reduces organic matter into simple compounds
- Reduces sludge volume
- Releases the remaining water more easily
- Reduces the coliforms by 99.8 percent in 30 days

Aerobic Sludge Digestion

This particular process functions in much the same way as an activated sludge unit, with the feed to the aeration tank being sludge from the primary and secondary sedimentation basins. This process requires adequate mixing and a dissolved oxygen level range of 1.0 to 1.5 mg/l. The detention time required for treatment of sludge is from 20 to 30 days with removals of supernatants and sludge from the digester to maintain a consistent feed rate.

For additional information, see:

Ch. 6, Washington State Treatment Plant Operator's Manual
Ch. 1 and 7, Eckenfelder-O'Connor
Ch. 14, ASCE STP Design
Ch. 26, Steel
Ch. 12, Imhoff-Fair

SLUDGE THICKENING

This process, usually found in the larger treatment plants, precedes digestion, vacuum filtration, or kiln drying. Sludge thickening is used to reduce the liquid volume of the sludge solids which have to be pumped to other treatment units. These treatment units then can be smaller because they do not have to handle the excess liquid.

There are two major types of sludge thickening operations:

- Gravity thickening. Sludge and aerated secondary effluent are introduced into a basin, much like a stirred sedimentation basin except deeper, which allows the concentration of solids from flocculation by interfacial contact and compaction by the weight of the overlaying water. This method can produce a solids content of 8% or greater. Not all sludge combinations will work in a gravity thickener, and testing of sludge produced by the treatment process will be necessary. In some cases, the addition of chemical flocculant will aid in the concentration of the sludge.
- Flotation thickening. This is usually used on sludges formed by biological reactors. This process combines sludge with a liquid which has been exposed to high pressure and contains large amounts of dissolved oxygen. Under less pressure in the thickening tank, air bubbles from the liquid attach themselves to the sludge particles and rise to the surface where the sludge is collected for further treatment.

For additional information, see:

Ch. 15, ASCE STP Design
Ch. 6, Washington State Treatment Plant Operator's Manual
Ch. 26, Steel
Ch. 14, Imhoff-Fair

SLUDGE CONDITIONING

The basic processes which are used in sludge conditioning are elutriation and chemical conditioning.

- Elutriation consists of mixing thoroughly 1 part of sludge with 2 parts of water and allowing separation of about 6 hours, followed by decanting the resulting elutriate and drawing off the sludge.
- Chemical conditioning consists of the addition of certain chemicals to coalesce particles in sludge which facilitates moisture removal by filtration. Some of the chemicals commonly used are:

Ferric chloride

Ferric sulfate

Lime and ferric chloride

Chlorinated coppeas

Aluminum sulfate

Chemical solutions

Polyelectrolytes

Activated silicates

Inorganic polyelectrolytes

For additional information, see:

Ch. 15, ASCE STP
Ch. 26 Steel
Ch. 14, Imhoff-Fair

SLUDGE DEWATERING

Some common methods for sludge dewatering are vacuum filtration, centrifuging, and sludge drying.

- Vacuum Filtration is widely used in the separation of liquids from concentrated suspensions, sludges, and slurries. The basic mechanism of this process is the passing of a cylindrical drum which rotates partly submerged through a container of sludge. The solids in the container are agitated to keep them in suspension. A vacuum which is applied between the drum deck and filter media causes the water to be removed while sludge is held on the filter media. Following this process, the sludge is buried in a sanitary landfill or incinerated. The supernatant can be disposed of by returning it to the elutriation tank or returned into the influent of the plant.
- Centrifuging removes water by centrifugal force which tends to force the heavier solids to the outside of the rotating flow stream much like the spin dry cycle of a washing machine.
- Sludge Drying is best suited for sludges which have been digested. The mechanism is that of a shallow sand filter for draining the sludge and air for drying in beds. The supernatant may be disposed of in the same manner as vacuum filtration liquids.

For additional information, see:

Ch. 7, Rich - Unit Operations of
  Sanitary Engineering
Ch. 26, Steel
Ch. 15, ASCE STP Design
Ch. 14, Imhoff-Fair

DISPOSAL OF SLUDGE

The final disposal of sludge is influenced by many factors:

- The character and composition of the sludge
- Availability of land for dumping of sludge cake or lagooning of wet sludge
- Whether or not regulatory agencies allow piping (deep water sludge outfall) or barging of sludge
- Local market possibilities for its use as fertilizer.

Coastal cities can dispose of sludge through barging or piping to sea, where still allowed. On land, it may be buried in swamps, abandoned quarries, and other lands which have no present use.

Incineration of raw or digested dewatered sludge is gaining popularity. At present, only larger cities are utilizing this process because of its added expense. In general, incineration of sludge is a wet combustion process in which sludge in solution or suspension goes through chemical oxidation processes under pressure.

For additional information, see:

Ch. 14, Rich - Unit Processes of
  Sanitary Engineering
Ch. 15, ASCE STP Design
Ch. 26, Steel
Short Course - Theory and Design
  of Advanced Waste Treatment
  Processes, U.C. Berkeley Extension

Appendix G

CONTROL AND METERING SYSTEMS

Various control and metering systems which are in common use in wastewater treatment plants are described in this section. It also indicates the uses and the limitations of these devices. The limitations are a function of physical/chemical makeup of the wastewater, the type of treatment units employed, sophistication of the plant personnel, economics, and the plant's maintenance program.

A comparison of devices indicated in this section should be made with those that will be encountered at the treatment plant to see if they are types which will supply the data needed and required to maintain proper plant performance.

The section on Problems and Solutions indicated the various problems which are commonly encountered with existing metering devices to help with solutions.

CONTROL SYSTEMS

Wastewater treatment plants use a variety of treatment processes. These processes usually fall into four categories: physical, biological, chemical, and electrochemical. In most plants, the processes are affected by temperature, weather, and day-to-day load variations. The nature of wastewater being high in solids' content and the inability of sensors to withstand fouling due to these solids makes total automation (computer control of the process) infeasible at the present time.

Most treatment plants in existence today use instrumentation which involves the measurement of physical variables, such as flow, level, pressure, and temperature. These controls are electric and pneumatic mechanisms in conjunction with hydraulic equipment. These controls can be divided into two basic types:

- On-off - used for the activation of pumps, alarms, etc.
- Modulating - where the regulation of valves or other equipment is accomplished in proportion to a measurement (ratio control).

The treatment systems utilize these controls to regulate or determine recirculation rates or controllers that set recirculation flow at a ratio to some other variable. The greatest present use for instruments and controls is in the treatment of sludge, where the use of density monitoring equipment to maintain optimum raw sludge density in the digester is becoming common.

Other examples of automated control include: temperature control, gas volume sampling, and sludge level measuring equipment.

What most systems lack is redundancy; there are no built-in back-up systems for emergency failures. A second shortcoming is the lack of an information feedback system. If a switch on the operating console activates a pump, there is no return loop which indicates to the operator that the pump has in fact been activated and is working.

FLOW MEASUREMENT

Differential Measuring Devices and Instruments

Devices which measure flow and are used with differential measuring instruments are all descendants of the Venturi tube and are considered primary devices. Most of the devices require very little head and can handle flows which contain suspended solids. Larger differential (high-head recovery) devices, such as the Dall tube, amplify a small, purely static change in head to a value which can be conveniently measured with secondary instruments. The high-head recovery, Venturi-type devices are not applicable to "dirty" fluids (high solids content) except in conjunction with a purging system. Other exceptions are the flow nozzle and the Lo-Loss tube.

Orifice plates were originally developed for use on gas flows, but have been applied for use in the masurement of water which contains little or no solids in suspension.

In general, wastewater can be successfully metered with the long- and short-type Venturi tube, flow nozzle, and Lo-Loss tube. It must be realized that an orifice that is too small produces large permanent pressure drops and is uneconomical. On the other hand, a too-large orifice measurement can be affected by inlet flow disturbances. The choice of device has to be carefully considered.

Secondary Instrument System

These instruments measure the differential produced by the primary devices and convert the result into a signal for transmission or into a motion for indication recording or totalization. These instruments include mercury manometer, diaphragm meter, and various types of force-balance and motion-balance pneumatic and electronic transmitters.

Other Flow Metering Devices

- Magnetic devices utilize Faraday's Law to measure flow in a magnetic field. With a steady magnetic field, the volume of flow rate is directly proportional to the generated voltage; a voltmeter calibrated in volume flow units is then read for the flow measurement. The basic advantages: it has no head loss; it handles solids in suspension; it has no liquid connections; and it has an electronic output ready for in-plant transmission.

- Propeller meters utilize the velocity head and convert it into mechanical power which is linear and translatable into velocity. This type of system is useful where frequent totalization readings are necessary.
- Open Channel Devices -

  Weirs are of two basic types: rectangular and V-notch. In weir measurement water abruptly flows through a precise cross section. The nappe, or profile of water over the weir, must be completely aerated in order to have precise flow measurement with a minimum head loss.

  Flumes, a modification of the basic weir concept, are designed primarily to reduce head loss that occurs in weirs. This is accomplished by having the sides of the channel vary gradually to the desired cross section.

  Open-channel flow nozzle is a combination of flume and weir; this device can handle solids effectively but does not have the head recovery characteristic of the in-line flume.

In general, the flow-through of a weir- or flume-type device is a function of fluid level. The three basic devices for measuring this level are float-and-cable, the in-flume float, and the bubble tube.

In determining if the type of measuring device is suitable for the location in the treatment system, the following should be considered:

- Probable flow range
- Acceptable head loss
- Required accuracy
- Fouling ability of wastewater

The diversity of instruments for measuring the various parameters precludes their individual description in a broad overview. The level of sophistication of these instruments is rapidly increasing. Devices which are available and are used for pressure, level, temperature, and analytical measurements consist of:

Pressure

- Bourdon tube
- Spiral and helical elements

- Bellows and diaphragm elements
- Wire strain gauges

Level

- Bubble tube
- Diaphragm box

Temperature

- Mechanical (filled thermal) system
- Electrical systems

Analytical Measurement

Type of Measurement	Type of Electrical Signal
• pH; oxidation-reduction potential (ORP) (although many ions can be measured with selective ion electrodes)	
• Residual chlorine; DO	Voltage or amperage
• Turbidity; color	Amperage or resistance
• Conductivity	Resistance

For additional information, see:

Instrumentation and Control in Water Supply and Wastewater Disposal by Russell H. Babcock, P.E.;

Introduction to Chemical Process Control by Daniel D. Perlmutter;

Ch. 19, ASCE Treatment Plant Design;

Ch. 11, Operation of Wastewater Treatment Plants, EPA.

Appendix H

MAINTENANCE DATA

This section of the manual describes the basic components of a maintenance system. It describes the type of filing system which could be employed for maintenance data, how to set up such a filing system, and the type of information it should contain.

By comparing the maintenance records at the treatment plant with this guide and manufacturer's maintenance schedule, the plant's maintenance program can be evaluated.

It is imperative that a record be kept of the service requirements of every piece of major equipment in the plant and when and how frequently service is required. Therefore, a system is needed to keep a complete record of maintenance requirements. Such a system should provide a permanent record of all maintenance work together with the advanced scheduling of preventive maintenance for an entire year. The system should also provide the maintenance work schedule for any given day. To be efficient, the system should contain the following five files:

(1) preventive maintenance records

(2) the preventive maintenance schedule for each piece of equipment

(3) specifications on each major piece of equipment, the supplier, and where spart parts can be purchased,

(4) spare parts inventory, and

(5) instructions for operation and maintenance of each item of major equipment.

As a first step in setting up any maintenance record system, each structure and each major piece of equipment should be assigned a file number. A simple means of doing this is assigning each area or each structure within a treatment plant a block of 1000 numbers; and each equipment item in each area or structure requiring maintenance can be assigned an individual number within the block of 1000. Therefore, sufficient open numbers remain to provide for any additional equipment which may be required within that area or structure in the future. The assigned numbers will serve to identify each item of equipment in all of the plant records described above and should also be used to catalog spare parts.

The file of preventive maintenance requirements mentioned in Item 1 above should contain one sheet for each item of plant property which requires periodic attention or maintenance, filed numerically. Listed thereon should be all pertinent requirements with respect to periodic maintenance including frequency, number of men required, and the estimated time of performance. These sheets are to be filed numerically as recommended above and maintained as a reference file.

The file for preventive maintenance scheduling as mentioned in Item 2 above should show the equipment number and the key information given on the preventive maintenance sheet, together with a specific day for the performance of each item of work. Space should be provided on each equipment card for the operator to know the work items performed and the date of performance. A systematic means of pulling these cards on the dates on which maintenance work is required should be devised.

The equipment data file mentioned in Item 3 above should contain cards with complete nameplate data for each item of equipment. These cards may also be used to show the type of lubricant required, together with the nature of any special service requirement. The cards should also be filed numerically in accordance with the recommended system.

The operation and maintenance instruction file mentioned in Item 4 above should contain information relating to maintenance, operation, and servicing of each item of equipment. This information should be filed numerically in accordance with the recommended system. Specifically, the file should contain all maintenance and operation manuals furnished by equipment manufacturers, parts lists, dimension drawings, and other informative literature.

In order to maintain an effective maintenance program it is recommended that the maintenance record system be kept up to date faithfully and consistently. Service requirements should be modified as equipment ages and flow rates increase. All modifications to major plant equipment should be recorded in the maintenance record system.

A complete set of the as-built drawings of the wastewater treatment plant should be available for the ready use of the plant operators. The plant operators should record on these plans all changes that are made in the plant piping, equipment, and electrical circuitry. The original drawings of the treatment plant should be updated at least yearly in accordance with the changes made on site.

For additional information, see:

Ch. 11, Operation of Wastewater
Treatment Plants, EPA.

Appendix J

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Appendix K

GLOSSARY

The terminology used in the glossary of this manual reflects particular meanings of those words and definitions which clarify the basic information compiled from the various texts, journals and technical papers used.

BIOCHEMICAL OXYGEN DEMAND (BOD)	The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions. It is not related to the oxygen requirements in chemical combustion, being determined entirely by the availability of the material as biological food and by the amount of oxygen utilized by the microorganisms during oxidation.
BIOLOGICAL OXIDATION	The process whereby living organisms in the presence of oxygen convert the organic matter contained in wastewater into a more stable or a mineral form.
BY-PASS	A pipe or conduit which permits wastewater to be moved around a wastewater treatment plant or any unit of the plant. This is usually found in plants which receive combined flow or high infiltration rates and is utilized to prevent flooding of units, or in case of shutdown for repair work, flow can be moved to parallel units.
CHLORINE CONTACT CHAMBER	A detention basin where chlorine which has been diffused through the treated effluent is being held a required time to provide the necessary disinfection.
CHLORINE DEMAND	The difference between the amount of chlorine added to the wastewater and the amount of residual chlorine remaining at the end of a specific contact time. The chlorine demand for given water varies with the amount of chlorine applied, time of contact, temperature, pH, nature and amount of impurities in the water.
COMBINED AVAILABLE RESIDUAL CHLORINE	That portion of the total residual chlorine remaining in water or wastewater at the end of a specified contact period which will react chemically and biologically as chloramines, or organic chloramines.

COMBINED RESIDUAL CHLORINATION	The application of chlorine to water, wastewater, or industrial wastes in an amount to produce directly or through the distribution of ammonia, or of certain organic nitrogenous compounds, a combined chlorine residual.
COMBINED SEWER SYSTEM	A transport system which carries both sanitary wastewater and storm or surface water runoff.
DENITRIFICATION	Chemically-bound oxygen in the form of either nitrates or nitrites is stripped away for use by microorganisms. This produces nitrogen gas which can bring up floc in the final sedimentation process. It is an effective method of removing nitrogen from wastewater.
EFFLUENT	Wastewater or liquid - raw, partially or completely treated; flowing from a basin, treatment process, or treatment plant.
ENDOGENOUS RESPIRATION	An auto-oxidation of cellular material that takes place in the absence of assimilable organic material to furnish energy required for the replacement of worn-out components of protoplasm.
FOOD TO MICROORGANISM RATIO	An aeration tank loading parameter. Food may be expressed in pounds of suspended solids, COD, or BOD added per day to the aeration tank, and microorganisms may be expressed as mixed liquor suspended solids (MLSS) or mixed liquor volatile suspended solids (MLVSS) in the aeration tank. The flow (volume per unit time) applied to the surface area of the clarification or biological reactor units (where applicable).
HYDRAULIC LOADING	The flow (volume per unit time) applied to the surface area of the clarification or biological reactor units (where applicable)
INFILTRATION	Groundwater that seeps into pipes through cracks, joints, or breaks.
INFLUENT	Wastewater or other liquid - raw or partially treated; flowing into a reservoir, basin, treatment process or treatment plant.
MIXED LIQUOR	A mixture of activated sludge and wastewater undergoing activated sludge treatment in the aeration tank.

ORGANIC LOADING	Pounds of BOD applied per day to a biological reactor
OVERFLOW RATE	One of the criteria for the design of settling tanks in treatment plants; expressed in gallons per day per sq ft of surface area in the settling tank.
OXYGEN UPTAKE RATE	The amount of oxygen being utilized by an activated sludge system during a specific time period.
POSTCHLORINATION	Application of chlorine to the final treated wastewater or effluent following plant treatment.
PRECHLORINATION	Chlorination at the headworks of the plant; influent chlorination prior to plant treatment.
RAW SLUDGE	Settled sludge promptly removed from sedimentation tanks before decomposition has much advanced. Frequently referred to as undigested sludge.
RECIRCULATION RATE	The rate of return of part of the effluent from a treatment process to the incoming flow.
SANITARY SEWER SYSTEM	A sewer intended to carry wastewater from homes, businesses, and industries. Storm water runoff sometimes is collected and transported in a separate system of pipes.
SLOUGHINGS	Trickling filter slimes that have been washed off the filter media. They are generally quite high in BOD and will degrade effluent quality unless removed.
SLUDGE AGE	In the activated sludge process, a measure of the length of time a particle of suspended solids has been undergoing aeration expressed in days. It is usually computed by dividing the weight of the suspended solids in the aeration tank by the daily addition of new suspended solids having their origin in the raw waste.
SLUDGE DENSITY INDEX	A term also used in the expression of settling characteristics of activated sludge 100/S.V.I.

SLUDGE VOLUME INDEX (SVI)	A numerical expression of the settling characteristics of activated sludge. The ratio of the volume in milliliters of sludge settled from a 1000 ml sample in 30 minutes to the concentration of mixed liquor in milligrams per liter multiplied by 1,000.
SUSPENDED SOLIDS (SS)	Solids that either float on the surface of, or are in suspension in, water, wastewater, or other liquids, and which are largely removable by laboratory filtering.
WASTED SLUDGE	The portion of settled solids from the final clarifier removed from the wastewater treatment processes to the solids' handling facilities for ultimate disposal.
WET WELL	A compartment in which a liquid is collected and held for flow equalization and then pumped (by systems' pumps for transmission through the plant).